S·A·E JOURNAL

OCTOBER 1930

S. A. E. JOURNAL

Published by the Society of Automotive Engineers, Inc., 29 *W. 39th St., New York*
Cable Address: Autoeng *Telephone:* Longacre 7170

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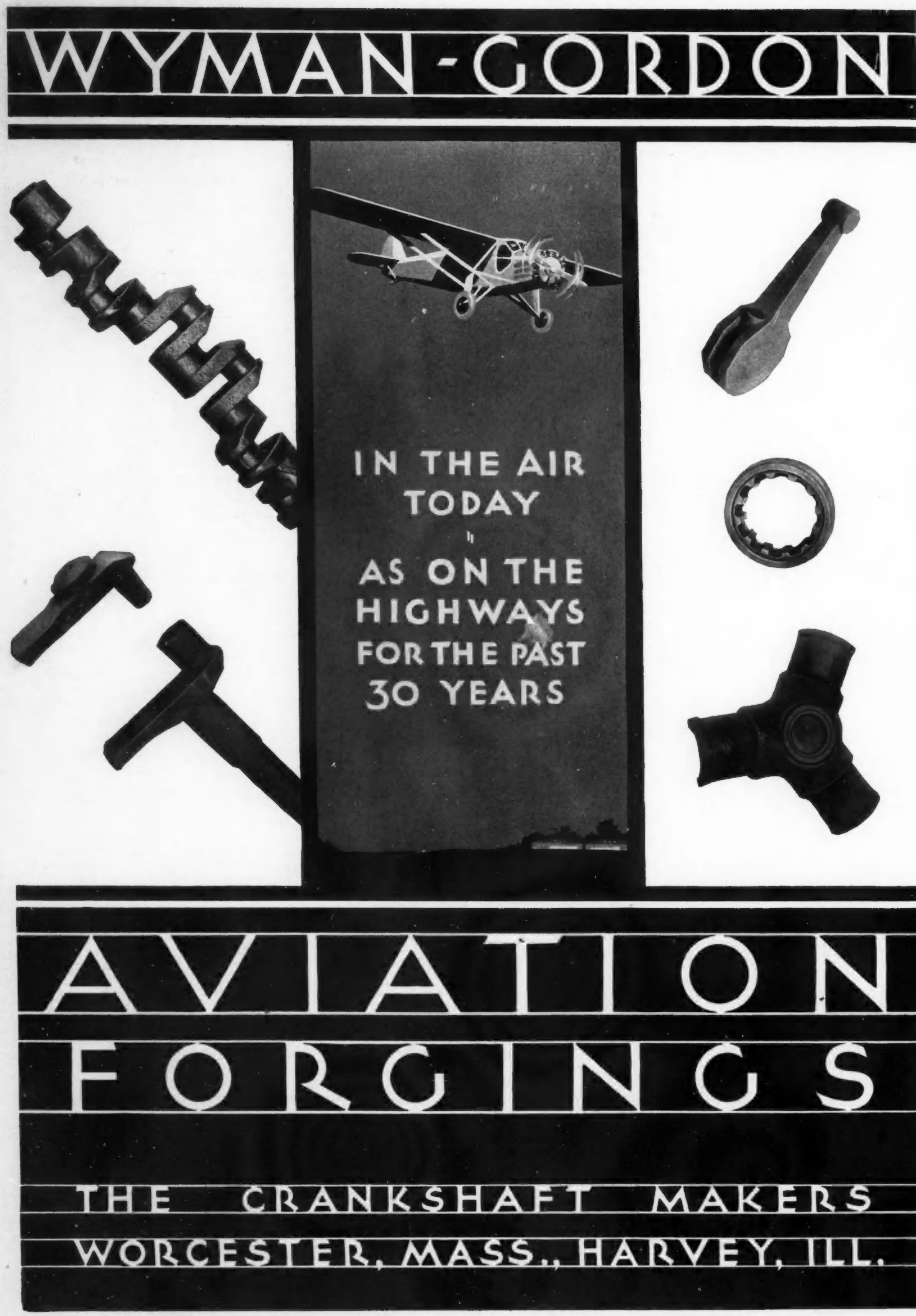
The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.


WYMAN-GORDON
IN THE AIR
TODAY
AS ON THE
HIGHWAYS
FOR THE PAST
30 YEARS
AVIATION
FORGINGS
THE CRANKSHAFT MAKERS
WORCESTER, MASS., HARVEY, ILL.

S. A. E. JOURNAL

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Big Events in January

Plans for Annual Dinner in New York City and Annual Meeting in Detroit Promise Social and Technical Treats

COMING events cast their shadows before, goes the saying, and, judging from the magnitude of the shadows cast by the coming Annual Dinner and Annual Meeting, it may be foretold with authority that these events will be fraught with interest and importance. The Annual Dinner will be held Jan. 8 at the Hotel Pennsylvania, New York City; the Annual Meeting at the Book-Cadillac Hotel, Detroit, Jan. 19 to 23.

Shidle Assumes Meetings Committee Chairmanship

Norman G. Shidle, directing editor of the Chilton Class Journal Co., who has been active in the work of the Society for several years, has been appointed by the President to take up the duties of Chairman of the National Meetings Committee. This office was relinquished by John A. C. Warner when he assumed the responsibilities of General Manager of the Society.

Dinner on Thursday of Show Week

Plans of the Annual Dinner Committee show pron ise of an unusually interesting program for this affair, and an evening of enjoyment such as only a good toastmaster, a good speaker and food of rare excellence can assure may safely be anticipated. As is customary, the dinner will be held on Thursday evening of the New York Automobile Show Week, Jan. 3 to 10. The names of the principal speaker and the toastmaster are to be definitely announced in the very near future, according to the Annual Dinner Committee composed of Chairman W. T. Fishleigh, F. K. Glynn and B. J. Lemon. Also as usual the election of officers of the Society for next year will be announced at the Dinner.

Annual Meeting Program Mapped Out

The schedule of events for the five days of the Annual Meeting is rapidly taking definite shape under the sponsorship of the various S.A.E. Professional Activities Committees.

It has been planned to have, in general, only two or three papers presented at each session, thus leaving ample time for discussion of the points at issue brought out by the speakers.

Sessions under Sponsorship of Activities

Professional Activities that are sponsoring sessions at the Annual Meeting include the Aircraft, Aircraft-Engine, Diesel-Engine, Motor-Truck and Motorcoach, Passenger-Car, Passenger-Car Body, Production, and the Transportation and Maintenance Activities. In short, all the Activities of the Society, functioning through their Committees, will be represented on the Annual Meeting program, and it is evident that an imposing array of papers on technical automotive subjects will be the result.

Each of the Activities, with the exception of the Passenger-Car and Diesel-Engine, will sponsor one session. The Passenger-Car Activity is arranging for the programs of five sessions; namely, the Engine, Fuels and Lubricants, Detonation, Chassis, and General Development Sessions. The Diesel-Engine Activity is sponsoring two Diesel Sessions. In addition to those mentioned, the following sessions will be held: Body, Transportation, Aircraft, Aircraft-Engine, Motor-Truck and Motorcoach, and Production.

NORMAN G. SHIDLE

Questions of vital interest to men active in these particular branches of automotive engineering will be propounded, and problems peculiar to each field of activity, to be met by every engineer in his daily work, will be brought up for general discussion. There will also be a Standards Session, at which important standardization matters will be considered; a Fuel-Research Session, at which the results of investigation along these lines will be submitted; and a meeting of the Detonation Subcommittee, at which a report of the work of this Committee will be made.

Detroit Section To Be Dinner Host

One of the most looked-forward-to features of the Annual Meeting is the Dinner that is to be sponsored by the Detroit Section in cooperation with the parent Society. Those who have been present on similar occasions in the past are well acquainted with the virtues of the Detroit Section as host, and the members and guests attending the Annual Meeting this year may depend upon not being disappointed in their expectations of an extremely interesting evening.

Adherence to Time Schedule

The question of how much time should be allowed an author for the presentation of his paper, and the desirability of holding him strictly within this time limit, has often been considered by the National Meetings Committee. It was the subject of much discussion at French Lick last May, during the Semi-Annual Meeting. The result was a recommendation that each author be told in advance exactly how much time he would be allowed for his presentation and that this allotment of time be strictly adhered to. Returns on a questionnaire sent out by the Society to the secretaries of other technical organizations show that the rule among them is to adhere strictly to a time schedule.

Meetings Calendar

National Meetings of the Society

Production—Oct. 7 and 8
Book-Cadillac Hotel, Detroit
Production Dinner, Oct. 8

Transportation—Oct. 22 to 24
William Penn Hotel, Pittsburgh
Transportation Dinner, Oct. 23

Annual Dinner—Jan. 8
Hotel Pennsylvania, New York City

Annual Meeting—Jan. 19 to 23
Book-Cadillac Hotel, Detroit

October Section Meetings

Baltimore Section—Oct. 15
Subject—Maintenance

Buffalo Section—Oct. 14

Canadian Section—Oct. 15
Royal York Hotel, Toronto

Chicago Section—Oct. 7
Hotel Sherman; Dinner, 6:30 P. M.; Entertainment
Diesel Engines—Harte Cooke, McIntosh & Seymour Corp.
Also a surprise paper to be announced at the meeting

Cleveland Section—Oct. 15
Hotel Statler; Dinner 6:30 P. M.; Entertainment
Stainless Steel in the Automotive Industry—M. J. R. Morris, Republic Steel Corp. Discussion to be led by Orel A. Parker
Ten-Minute Searchlight-Talk—E. L. Shaner, editor of *Stock*

Detroit Section—Oct. 7 and 8
National Production Meeting of the Society; Book-Cadillac Hotel; Dinner on Oct. 8 sponsored by the Detroit Section

Indiana Section—Oct. 9
The Athenaeum, Indianapolis
Subject: Rust-Resisting Metals and Nitriding
Speakers: J. Muller, Leeds & Northrup Co., and a representative of the Republic Steel Co. Discussion led by Mr. Korp, of the Leeds & Northrup Co., followed by round-table discussion

Metropolitan Section—Oct. 16
A. W. A. Building, New York City; Dinner, 6:30
Free Wheeling—Delmar G. Roos, Chief Engineer, Studebaker Corp.
Motion pictures of the S.A.E. at the National Air Races, the Metropolitan West Point Outing and Early Activities of Other Sections

Milwaukee Section—Oct. 1
Milwaukee Athletic Club; Dinner, 6:30 P. M.
Subject: The Modern Outboard Motor, by F. T. Irgens, Chief and Research Engineer, and presented by W. J. Webb, Division Sales Manager, Outboard Motors Corp.

New England Section—Oct. 10
Hotel Kenmore, Boston; Dinner, 6:45 P. M.
Driving at Night—W. M. Johnson, Commercial Engineer, National Lamp Works, General Electric Co.

Northern California Section—Oct. (?)
San Mateo, Calif.; Curtiss-Wright Flying Field
Servicing and Maintaining Modern Aircraft Powerplants—Edward Cooper

Northwest Section—Oct. 3
Engineers Club, Seattle, Wash.; Dinner, 6:30 P. M.
Lubrication of Internal-Combustion Engines—Prof. F. E. Baender, Oregon State University

Oregon Section—Oct. 10
Service Managers' Program

Philadelphia Section—Oct. 15
Gliders—Lieut. Ralph S. Barnaby, U.S.N.

Pittsburgh Section—Oct. 22 to 24
National Transportation Meeting of the Society; William Penn Hotel; Dinner at 6:30 P. M. Oct. 23 sponsored by the Pittsburgh Section

Southern California Section—Oct. 3
City Club, Los Angeles; Dinner, 6:15 P. M.
Free-Wheeling Transmission—John E. Van Sant, Superintendent, Paul G. Hoffman Co.
Chrysler Multi-Mesh Transmission—Edward Seward, Greer Robbins Co.
Also a surprise speaker on a traffic subject

Syracuse Section—Oct. 7
Hotel Syracuse; Dinner, 6:30 P. M.
Latest Developments in Aluminum Alloy as Related to Aircraft and Automotive Industries—G. D. Welty, Aluminum Co. of America

Washington Section—Oct. 7
Diesel Engines for Commercial Vehicles

Wichita Section—Oct. 9
Green Parrot Inn; Dinner, 6:30 P. M.
Wind-Tunnel Session at Wichita University

Coming National Transportation Meeting

How to Save Money Without Reducing Service-Value to Public to Be Keynote of Discussion at Pittsburgh on Oct. 22 to 24

FLEET supervision and maintenance is to be given a preponderance of attention at the National Transportation Meeting to be held Oct. 22, 23 and 24 at the William Penn Hotel in Pittsburgh. This is in accordance with the evident desire of operators to save money at every point without impairing the value of the service rendered to the public by motorcoach and motortruck operation.

Not only will speakers at the technical sessions tell of methods whereby economies are being effected and better service rendered, but in the afternoon of the last day of the meeting the S.A.E. members and guests will have an opportunity to see such methods in actual practice at several plants in Pittsburgh through the courtesy of the management of the companies. The full program of the meeting is printed below.

Much of the value of attendance at the meeting will come from the getting of first-hand information from the men who have had experience in operating and maintaining large fleets and have evolved superior systems and methods. In open discussion, questions that may have been troubling the attendant can be asked and answers obtained from the speakers or others who very likely have solved similar difficulties. Under present economic conditions, such special information may have great immediate value. The desired information might not be brought out by any of the speakers or discussers, hence would not be obtained unless one were present to ask for it. And even if it were evoked, much of its value might be lost in an unavoidable delay of perhaps several months in its publication.

Obviously, the sooner any improved system or method can be put into operation, the sooner the benefits can be

Transportation Meeting Program

William Penn Hotel, Pittsburgh, Oct. 22 to 24

Wednesday, Oct. 22

9:30 A. M.—TECHNICAL SESSION

Chairman: A. H. Gossard, Middlewest Utilities Co.

(1) Selection of and Results Obtained from Motor-Vehicle Performance Indicating and Recording Instruments—C. W. Stocks, *Bus Transportation.*

12:00 Noon—ADJOURNMENT FOR LUNCHEON

2:00 P. M.—TECHNICAL SESSION

Chairman: F. C. Horner, General Motors Corp.

(1) Scientific Inspection of Motor-Vehicles and Their Units—H. B. Hewitt, Philadelphia Rural Transit Co.

(2) Motor-Vehicle Maintenance to Prevent Road Delays—P. V. C. See, Northern Ohio Light & Power Co.

(3) Motor-Coach Maintenance — L. V. Newton, Byllesby Engineering & Management Corp.

Thursday, Oct. 23

9:30 A. M.—TECHNICAL SESSION

Chairman: Dr. W. A. Gruse, Mellon Institute of Industrial Research

(1) Practical Methods for Determining and Comparing Tractive Ability—A. M. Wolf, Newark, N. J.

(2) Taking Advantage of Latent Heat of Cooling Water—Adrian Hughes, Jr., United Railways & Electric Co. of Baltimore

12:00 Noon—ADJOURNMENT FOR LUNCHEON

2:00 P. M.—TECHNICAL SESSION

Chairman: C. F. Kells, West Penn Electric Co.

(1) How the Principles of Economics in Motor-Vehicle Transportation Are Taught by Educational Institutions—Prof. J. W. Trimmer, Carnegie Institute of Technology

(2) Motor-Vehicle Maintenance Cost Reduced by Training Drivers—J. S. Lowe, Akron Transportation Co.

6:30 P. M.—S.A.E. TRANSPORTATION DINNER
Host: Pittsburgh Section

Toastmaster: Walter Rosenbaum, Vice-President and Treasurer, The Rosenbaum Co., Pittsburgh

Principal Speaker: F. R. Phillips, Vice-President, The Philadelphia Co., Pittsburgh

Friday, Oct. 24

9:30 A. M.—TECHNICAL SESSION

Chairman: J. F. Winchester, Standard Oil Co. of New Jersey

(1) Aluminum Alloys in Commercial Motor-Vehicles—F. D. Goll, Aluminum Co. of America

(2) United States Army Maintenance—Lieut.-Col. Brainerd Taylor, Office of the Quartermaster General, City of Washington

12:00 Noon—ADJOURNMENT FOR LUNCHEON

1:30 P. M. Sharp—Plant Visits

(a) Gulf Refining Co.

(b) Auto Truck Equipment Co.

(c) Equitable Auto Co.

derived from it. The meeting this month presents an opportunity that comes but once a year to secure valuable ideas from men who have made a thorough study of the various phases of fleet operation and have learned, perhaps at heavy financial cost, the more economical and successful methods, types of vehicle and equipment.

New Problems Arising Fast

That truck and motorcoach operators and railroad executives are keenly aware of the growing importance and the new problems of automotive transportation was shown by the large attendance at the National Transportation Meeting in Toronto last November and the joint conferences there with the American Railway Association.

Great changes in the transportation of both passengers and goods have come about within the last few years as the result of widespread highway improvement and the developments in motor-vehicles. Transportation engineers have had difficulty in keeping up with the demands of the public, whose traveling and shipping habits have changed almost over night. The rapid rise of motorcoach travel throughout the Country and the commercial effects resulting from short-haul motor-trucking have caused the railroads to supplement their long-established service with automotive activities, to alter their equipment and schedules and in some instances to make use of airplanes and motorcoaches to retrieve lost revenue or avoid future losses. More and more it is coming to be recognized that transportation is the service that the common carrier is selling and that it is incumbent upon him to provide it in its most economical, convenient and complete form, whether that be by railroad train, rail-car, motor-truck, motorcoach or airplane.

Transportation Economics Being Taught

Automotive transportation is undergoing scientific scrutiny and analysis. Suitable instruments for indicating and recording motor-vehicle performance are becoming of greater interest and importance. Inspection of the vehicles and their units, their repairing and maintenance are becoming recognized as worthy of real engineering skill. The economics of highway transportation calls for technical training of a high order, and several of our educational institutions are now offering courses in this subject.

Both the transportation of passengers and freight for revenue and the operation of service stations for the privately owned automobile present problems. Unregulated and uneconomic competition and abuses that have arisen as the result of chaotic conditions are costing so much that operating companies and individuals are demanding more careful scrutiny of costs. Engineers are now called upon to remove, as far as possible, the burden that has been upon the shoulders of practical operating and maintenance men. Their problem is complicated by the insistence upon physical and operating limitations by State regulating bodies interested in preservation of the highways and the safety of the users thereof.

Must Keep Abreast of Progress

Out of this situation will ultimately come as definite provisions for highway-transport engineering as has been the case in railroad fields. The work has been started in the universities and technical schools as well as in the operating plants, and in addition to the standard engineering subjects, courses are now being given that include automotive service practice, automotive electrical engineering, service management, financial organization, commercial law, and the training of drivers and maintenance and service men.

To avoid being left behind in the rapid progress that is being made in so many directions in the great field of automotive transportation, one needs to know what those in the forefront are doing, and the best way to get this knowledge is to be where they foregather to talk over their activities and problems, that is, the National Transportation Meeting of the Society.

Dr. Lewis Appointed Vice-President

At a meeting of the Council held at the Canterbury Golf Club, Cleveland, on Sept. 10, Dr. George W. Lewis, director of aeronautical research for the National Advisory Committee for Aeronautics, was appointed Vice-President of the Society to represent aircraft engineering to fill the unexpired term of office of Chance M. Vought, who passed away on July 25.

The Council was notified officially that E. S. Marks, of the H. H. Franklin Mfg. Co., had been named by the Nominating Committee of the Passenger-Car Activity Committee as nominee for Vice-President representing passenger-car engineering in 1931 to take the place of John A. C. Warner, originally nominated and later appointed Secretary and General Manager.

Section Territories Allocated

The allocation of territories to the various Sections of the Society under the new membership-dues plan announced in detail in the August, 1930, issue of THE JOURNAL, p. 132, was approved by the Council, to be effective as of Oct. 1, 1930. The territories as assigned are delineated in this issue of THE JOURNAL on the opposite page.

Following discussion of details of the Cumulative Technical Index to S.A.E. Publications for the last 25 years, the Council fixed the prices to be charged for the coming volume. These prices, together with full information regarding this index, are given in this issue on p. 479.

As submitted, a financial statement of the Society as of July 31, 1930, showed a balance of assets over liabilities of $244,269.20, this being $19,210.05 more than the corresponding figure for the same date in 1929. Gross income of the Society for the first 10 months of the present fiscal year amounted to $372,270.30, while the operating expense was $357,765.96. Income for the month of July, 1930, was $29,853.40 and the operating expense during the same month was $45,067.36.

Membership Applications Approved

One hundred eleven applications for individual memberships were approved, together with 14 transfers in grade of membership and 3 reinstatements. Five membership applications were reapproved. Ninety-nine additional applications, 6 transfers and 1 reinstatement and 1 reapproval, which had been acted upon by mail vote, were confirmed at the meeting.

Those present at the Council meeting were President Warner, Vice-Presidents Leighton, Scaife and McCain, Councilors Herrington, Parker and Teetor, Councilor-Elect Brumbaugh, Chairman Boor of the Standards Committee, Secretary Warner and Assistant General Manager Veal.

Section Territory Allotments

UNDER the new plan for the payment of membership annual dues, each Member and Affiliate Member Representative residing within the territory of a Section of the Society automatically becomes a member of that Section upon payment of his dues, as set forth in section SC6 of the amended Section Constitution and explained in THE JOURNAL for August, 1930, p. 132. And any Member or Affiliate Member Representative not residing in the territory of any Section and who is not already a member of any Section may become a member of a Section upon request.

So that every Member and Affiliate Member Representative may know whether he resides within the territory of any Section and, if so, which Section he belongs to, the Council, at a meeting in Cleveland on Sept. 10, approved the allotment of territories to the Sections as shown in the following list:

Territories by States and Counties

BALTIMORE SECTION

MARYLAND — Anne Arundel, Baltimore, Caroline, Carroll, Cecil, Frederick, Harford, Howard, Kent, Queen Anne, Talbot and Washington.

PENNSYLVANIA—Adams and York,

BUFFALO SECTION

NEW YORK STATE—Allegany, Cattaraugus, Chautauqua, Erie, Genesee, Livingston, Monroe, Niagara, Orleans and Wyoming.

CANADA, PROVINCE OF ONTARIO—Lincoln and Welland.

CANADIAN SECTION

PROVINCE OF ONTARIO—Brant, Dufferin, Durham, Elgin, Haldiman, Halton, Middlesex, Norfolk, Northumberland, Ontario, Oxford, Peel, Perth, Peterborough, Simco, Waterloo, Wellington, Wentworth and York.

CHICAGO SECTION

ILLINOIS—Boone, Cook, DeKalb, DuPage, Kane, Kankakee, Kendall, Lake, McHenry, Will and Winnebago.

INDIANA—Lake, Laporte, Porter and St. Joseph.

CLEVELAND SECTION

OHIO — Ashland, Ashtabula, Cuyahoga, Erie, Geauga, Huron, Lake, Lorain, Mahoning, Medina, Portage, Richland, Stark, Summit, Trumbull and Wayne.

DAYTON SECTION

OHIO—Allen, Auglaize, Butler, Champaign, Clark, Clermont, Clinton, Darke, Delaware, Fayette, Franklin, Greene, Hamilton, Hardin, Highland, Logan, Madison, Marion, Miami, Montgomery, Preble, Shelby, Union and Warren.

DETROIT SECTION

MICHIGAN—Genesee, Ingham, Jackson, Lapeer, Lenawee, Livingston, Macomb, Monroe, Oakland, Saginaw, Saint Clair, Shiawassee, Washtenaw and Wayne.

OHIO—Lucas.

CANADA, PROVINCE OF ONTARIO—Essex.

INDIANA SECTION

INDIANA — Adams, Allen, Bartholomew, Brown, Blackford, Boone, Carroll, Cass, Clinton, Decatur, DeKalb, Delaware, Fayette, Grant, Hamilton, Hancock, Henry, Howard, Huntington, Jay, Johnson, Madison, Marion, Miami, Monroe, Montgomery, Morgan, Putnam, Randolph, Rush, Shelby, Tippecanoe, Tipton, Union, Wabash, Wayne, Wills and Whitley.

METROPOLITAN SECTION

NEW YORK STATE—Kings, Nassau, New York, Orange, Putnam, Queens, Rockland, Suffolk and Westchester.

CONNECTICUT—Fairfield and New Haven.

NEW JERSEY—Bergen, Essex, Hudson, Hunterdon, Midlesex, Monmouth, Passaic, Somerset, Sussex, Union and Warren.

MILWAUKEE SECTION

WISCONSIN—Dane, Dodge, Fond du Lac, Jefferson, Kenosha, Milwaukee, Ozaukee, Racine, Rock, Sheboygan, Walworth, Washington, Waukesha and Winnebago.

NEW ENGLAND SECTION

MASSACHUSETTS—Barnstable, Bristol, Dikes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, Suffolk and Worcester.

RHODE ISLAND—Bristol, Kent, Newport, Providence and Washington.

NORTHERN CALIFORNIA

CALIFORNIA—Amador, Alameda, Alpine, Butte, Calaveras, Colusa, Contra Costa, Del Norte, Eldorado, Fresno, Glenn, Humboldt, Inyo, Kings, Lake, Lassen, Madera, Marin, Mariposa, Mendocino, Merced, Modoc, Mono, Monterey, Napa, Nevada, Placer, Plumas, Sacramento, San Benito, San Joaquin, San Mateo, Santa Clara, Santa Cruz, Shasta, Sierra, Siskiyou, Soland, Sonoma, Stanislaus, Sutter, Tehama, Trinity, Tuolumne, Tulare, Yolo and Yuba.

NORTHWEST SECTION

WASHINGTON — Adams, Asotin, Benton, Chelan, Clallam, Columbia, Douglas, Ferry, Franklin, Garfield, Grant, Grays Harbor, Island, Jefferson, King, Kitsap, Lewis, Lincoln, Mason, Okanogan, Pacific, Pend Oreille, Pierce, San Juan, Skagit, Snohomish, Spokane, Stevens, Thurston, Walla Walla, Whatcom, Whitman and Yakima.

OREGON SECTION

OREGON—Baker, Benton, Clackamas, Clatsop, Coos, Crook, Curry, Deschutes, Douglas, Gillian, Grant, Harney, Hood River, Jackson, Jefferson, Josephine, Klamath, Lake, Lane, Lincoln, Malheur, Marion, Morrow, Multnomah, Polk, Sherman, Tillamook, Umatilla, Union, Wallowa, Wasco, Washington, Wheeler and Yamhill.

WASHINGTON—Clarke, Cowlitz, Skamania and Wahiakukum.

PHILADELPHIA SECTION

PENNSYLVANIA — Berks, Bucks, Carbon, Chester, Columbia, Dauphin, Delaware, Lackawanna, Lancaster, Lebanon, Lehigh, Luzerne, Monroe, Montgomery, Montour, Northumberland, Philadelphia and Schuylkill.

DELAWARE—New Castle.

NEW JERSEY—Atlantic, Burlington, Camden, Gloucester and Mercer.

PITTSBURGH SECTION

PENNSYLVANIA — Allegheny, Armstrong, Beaver, Butler, Cambria, Clarion, Fayette, Greene, Indiana, Lawrence, Mercer, Vanango, Washington and Westmoreland.

WEST VIRGINIA—Brooke, Hancock, Marshall and Ohio.

OHIO—Columbia and Jefferson.

ST. LOUIS SECTION

ILLINOIS—Bond, Clinton, Greene, Jersey, Macoupin, Madison, Monroe, Montgomery, Randolph, Sangamon, St. Clair and Washington.

MISSOURI—Franklin, Jefferson, Lincoln, Saint Charles, Sainte Genevieve, Saint Francois, Saint Louis and Warren.

SOUTHERN CALIFORNIA SECTION

CALIFORNIA—Imperial, Kern, Los Angeles, Orange, Riverside, San Bernadino, San Diego, San Luis Obispo, Santa Barbara and Ventura.

SYRACUSE SECTION

NEW YORK STATE—Broome, Cayuga, Chemung, Chenango, Cortland, Madison, Oneida, Onondaga, Ontario, Oswego, Schuyler, Seneca, Tioga, Tompkins, Wayne and Yates.

WASHINGTON SECTION

DISTRICT OF COLUMBIA.

MARYLAND—Calvert, Charles, Montgomery, Prince Georges and Saint Marys.

VIRGINIA—Accomac, Amelia, Brunswick, Caroline, Charles City, Chesterfield, Clarke, Dinwiddie, Essex, Fairfax, Fauquier, Gloucester, Greensville, Hanover, Henrico, Isle of Wight, James City, King and Queen, King George, King William, Lancaster, Loudoun, Lunenburg, Mecklenburg, Middlesex, Nansemond, New Kent, Norfolk, Northampton, Northumberland, Nottoway, Princess Anne, Prince George, Prince William, Richmond, Southampton, Spotsylvania, Staffor , Surrey, Sussex, Warren, Warwick, West Moreland and York.

WICHITA SECTION

KANSAS—Allen, Barber, Barton, Butler, Chase, Chatauqua, Cowley, Elk, Ellsworth, Greenwood, Harper, Harvey, Kingman, Labette, Marion, McPherson, Montgomery, Neosho, Pratt, Reno, Rice, Saline, Sedgewick, Stafford, Sumner, Wilson and Woodson.

Cleveland Section Outing

THE opening gun of the Cleveland Section season was fired Saturday afternoon, Sept. 13, at the Aurora Country Club, on what is regarded as one of the sportiest golf courses in the Middle West. Its location, about midway between Cleveland and Akron, brought out nearly 70 members and guests from all parts of the Section territory. Of these, 53 remained to enjoy a steak dinner served at the clubhouse. Arrangements for the golf tournament were well handled by a committee consisting of C. L. Oestermeyer, chairman; Carl T. Klug and Secretary Hoy Stevens.

Golf proved the major activity of the outing, with bridge participated in

later in the afternoon and during the evening by a small group. A horseshoe-pitching tournament, which had been announced as one of the athletic events, had to be abandoned, the official reason being given as the failure of the stake-driving machine.

Results in the various events of the golf tournament, as worked out by Chairman Dale S. Cole, Past-Chairman Ferdinand Jehle, and the Outing Committee, are as follows:

Low Gross—Joe Shea, first; W. M. Horton, Jr., second; David Benjamin, third.

Medal Handicap — W. C. Robbins, first; C. T. Klug, second; R. M. Brown, third.

Long Drive—Richard Digney, first; W. M. Horton, second; Walter Howard, third.

Blind Par—T. R. Stenberg, first; Frank Jardine, second; Harry R. Portugal, third.

Oregonians Discuss Compression

Favary Elucidates Cause of Detonation and Section Members Report Fuel Economy Effected

THE thermal efficiency of the automobile gas engine is very largely dependent upon the compression ratio, said Ethelbert Favary, consulting engineer for the Moreland Motor Truck Co., when discussing high-compression engines before the Oregon Section at its first fall meeting, Friday evening, Sept. 12, at the Multnomah Hotel in Portland. Efforts of the oil companies to increase the production of gasoline by including distillates lower and lower in the hydrocarbon scale, at the same time that designers are endeavoring to increase the compression ratio, lead the automotive engineer into many difficulties, pointed out Mr. Favary.

Knocking within the combustion-chamber used to be attributed to one of two causes: the spark too far advanced or premature ignition due to excessive carbon deposits. Use of lower-gravity fuels with higher compression-ratios developed a new kind of knock, one that acted more like a detonation.

What Investigation Has Shown

Investigation of this problem by means of indicator diagrams showed that momentary pressures were developed that were many times what they should have been. Comparison of the position of these points of high pressure with the time of the revolution when the knock occurred showed that these high pressures were causing the knocks. Sometimes pressures were obtained that were sufficient to actually expand the cylinder-wall.

Further investigation of this problem by means of a spectroscope arranged to be set at different positions relative to the power stroke developed the fact that, while in an engine of lower compression-ratios burning a higher-test fuel the flame in the cylinder showed blue, a cylinder developing a detonating knock gave a condition of a blue flame at the beginning of the burning, this blue flame changing to green just before detonation, then to white at the time of detonation and then changing back to blue again.

Using kerosene as a fuel, it was found that a white flame developed at three different points during the combustion, indicating detonation at three different periods. Using fuel oil, five detonating points were indicated.

Starting with hexane, the formula for which is C_6H_7, the paraffin hydrocarbon series follows the formula $C_nH_{2n}+2$ down the series with increasing carbon content. A study of the molecular structure of these hydrocarbons shows that the atoms of carbon are arranged in a long line surrounded by the atoms of hydrogen. The greater the carbon content, the longer will be the molecules. Indications are that the oxygen attacks the molecules from the ends first. The long molecules of the lower hydrocarbons seem to burn for a time and then crack up, exposing a greater number of molecule ends to the action of the oxygen. The white flame observed probably is either an indication of this breaking-up action or of the accelerated chemical reaction resulting from exposure of the unstable molecule ends.

Three Ways to Prevent Knocking

Detonation can be eliminated by decreasing the compression ratio, by introducing small quantities of inert gases, such as exhaust gases, and by introducing in the fuel some chemicals that tend to slow up combustion, such as tetraethyl lead.

The more than 40 members and guests present at the meeting found Mr. Favary's treatment of the subject very instructive and the presentation of more than usual interest. Many questions were asked and a lively discussion was participated in by most of those present. A question was asked concerning the method of carbureter adjustment by means of exhaust-gas analysis and, in answer, W. A. Gill gave his experience with the use of the Orsat apparatus on customers' cars. Use of the apparatus in every instance resulted in an increase in fuel economy, he said. H. W. Drake gave some of his experiences with the method applied to a fleet of trucks over a period of several years and said that considerable saving of fuel had been effected each year.

Bisons Charge Buffalo Airport

Aerial Rides, Demonstrations and a Stout Talk Draw 200 *Section Members*

ATTRACTIONS galore started the new season of the Buffalo Section off with an attendance of 200 at its combination outdoor-indoor meeting on Sept. 20. The afternoon from 4 to 6:30 o'clock was spent at the Buffalo Airport, where the program included aerial rides, inspection of the installation of radio in a mail plane, a demonstration of parachute packing and dummy dropping, observation of airport operations and weather reporting, demonstrations of landing with Goodyear Airwheels, aerial acrobatics by pilots from the Army, the Navy, the Consolidated Fleet, and the Curtiss and the Kinney Flying Services, a speed-course demonstration in the Curtis Chieftain and a balloon-chasing contest. All the events went off as scheduled and proved highly interesting to the visitors at the airport.

In the evening the members proceeded to the Trap and Field Club for dinner, where they discussed one with another the events of the afternoon during the repast and, following the coffee and cigars, enjoyed a dissertation on The Possibilities of Passenger Airlines, delivered by William B. Stout, the inimitable "Bill." Seated at the speaker's table were:

Section Chairman Marsden Ware; Ralph Badger, Secretary of the Aeronautic Association; Nathaniel Duffy, manager of the Buffalo Airport; Major Satterfield, organizer of the first aeronautic club; Samuel Botsford, representing the Chamber of Commerce of Buffalo; Charles Ward Hall, of the Hall-Aluminum Aircraft Co.; C. Roy Keys, of the Curtiss Aeroplane & Motor Co.; Ted Knight, manager of the Sky View Lines; and A. J. Underwood, director of Section activities for the Society.

Air Travel of the Future

"There is no doubt in my mind that in the future we shall see airplanes leave New York City every hour for the Pacific Coast with a full load of about 100 passengers, and make it a paying proposition," declared Mr. Stout. Asserting that the people who travel by airplane at present are accustomed to a speed of about 100 m.p.h. and are taught that a city 200 miles distant is only 2 hr. away by airplane, the speaker said that we must increase the speed and performance of the passenger-carrying planes and render additional service, giving the passengers 200 m.p.h. The speed of the Ford tri-motor transports has been increased by changing the wing angle, putting pants on the wheels and making a few other minor improvements.

Better visibility for those who travel by airplane must also come, according to Mr. Stout, for if passengers could see the horizon ahead instead of the ground below there would be less tendency to sickness in the larger planes.

Will Supersede Surface Travel

Travel by air, predicted the speaker, will be no more unusual than travel by land in the not far-distant day. Air transportation is likely to supersede surface travel because the land and sea do not present obstacles to continuous journeys by air. As for safety, he stated that the Stout Air Lines have carried 137,000 passengers and as yet have had no accident. But the airplanes of the future must carry more passengers, not only in actual number, but in relation to horsepower, per pound of fuel and per square foot of wing area.

Improvements in the mechanical equipment of airplanes, more and larger airports, more frequent and complete weather reports and other factors are contributing to safety, and the successful passenger lines are slowly making the public air-minded. Economies in airline equipment is the solution of the profit problem for the air-transport lines, according to Mr. Stout, and it is the transport that will lead the way in engineering development for all types.

Everything connected with aviation in the United States is years ahead of anything abroad, according to the speaker, who declared that we are at least five years ahead of Europe in passenger-line equipment and operation. Step by step the engine and plane manufacturers have increased the passenger capacity of airplanes, but we shall have to design airplanes in the future that will carry 100 to 150 passengers, keep them on regular schedule and give the passengers more comfort and luxuries than they now have.

Aviation Was Oversold

President Warner Tells Indiana Section What Is Wrong and the Remedy

CREATION of a device or devices as radically new as was the electric starter upon its public inception nearly 20 years ago is needed to effect a quick restoration of the automotive, and particularly the aviation, business to its normal production stride, was one of the keynotes of the address made by President Edward P. Warner, of the Society, speaking before 250 members and friends of the Indiana Section at the first dinner-meeting of the Section's fall season at the Athenaeum in Indianapolis the night of Sept. 18.

Choosing the Business Depression and the Engineer as his subject, Mr. Warner spoke with particular reference to the automobile and the aviation and allied industries. Intense depression, he said, always results from one of two factors: Preliminary overselling and exaggeration of the public demand, or insufficient obsolescence of the product. Both of these are at base the fault of the engineer or of those who direct them and their efforts. Right now, when we need the greatest research and engineering advancement, we find research and engineering development being restricted by the makers of automotive vehicles; and of all classes the airplane needs radical advancement in order to bring about a more rapid obsolescence.

Much the same yardstick may be applied to merchandising plans and advertising, though in different proportions to the automobile and the aviation fields. The overselling in the automobile field last year was a case of exaggerated estimate of the public demand, while in the airplane field the overselling took the form of overselling the usefulness of the product, with the result that at the end of last year many purchasers of airplanes found themselves with large investments that were of little real value in usefulness to them but of great upkeep expense. This is one of the main factors that have reacted adversely on the business.

Can Create a New Market

While the automobile has advanced much too slowly, Mr. Warner believes that the progress of aviation has been made even slower. He pointed out that some of the advanced airplanes of 1919 and 1920 may still be ranked favorably with ships of a modern vintage; this in spite of notable developments and of some great engineering strides that have not yet reached the field of production, let alone merchandising. Were it possible to manufacture and sell at a reasonable price our planes already past the design stage, they might make obsolescent whole classes of present aircraft, and therefore create a brand new market that would lift us out of the slough of despond in which we wallow.

With more advanced planes, with lower costs and selling price and better service facilities, Mr. Warner believes we can go ahead much faster even in difficult selling conditions. With private planes having much slower landing-speed, that can almost fly themselves as can some experimental types not being developed, the public will accept flying at its true worth, not expecting miracles and not fearing it as much as it fears today the average type that is not radically different from airplanes of some years ago. This is an engineering and a production task that engineers can accomplish if management will spend as it should for research and development work.

That the aviation industry is not altogether to blame for the overselling done in the last two years was stressed in anecdotes of Reliability Tour incidents when chamber-of-commerce-rotarian types of laymen called down professional flying men because "you are so close to air travel and flying that you do not get the real vision of the thousands and thousands of private planes we, the common people, will acquire in the next year or so." A prominent eastern banker, "one of an entire school of mackerel", was also quoted who last summer berated a hard-headed aviation executive for foreseeing slow and painful growth and not a leap to the skies. "Why, man alive, young man, you have no idea of the swift and certain expansion your industry is headed for! For instance, in a few months Blank stock will jump 100 points as certainly as I am to breathe my next breath. Why not underwrite your future and make a few millions yourself?" That stock now is not worth 1/25th of its quotations of last summer, Mr. Warner drily added.

What Will Make Business Good

Business in the air trade will be good, according to the speaker, when engineers and technical men of the trade are permitted to make the airplanes more reliable and more economical, the engines better and cheaper, transport planes more economical to maintain, and private planes as easy

to fly and to operate as are automobiles. The aviation industry will keep pace with the automobile industry when its products are comparably as simple to operate and maintain as motor-cars and as easy to service or have serviced properly. Speed, safety, reliability, economy and convenience are the chief points in aeronautic construction that at one time or another have been stressed. We must strike a balance among all these and not neglect, as we have in the past, the items of convenience, of comfort and passenger flying-ease, for it will become increasingly necessary to advance comfort in air travel faster.

As illustration matter, the films of the Pan-American Airways (West Indies Section) were shown and received with great interest, as were the films of the S.A.E. at the National Air Races in Chicago. Louis Schwitzer, Section Chairman, presided, and C. B. Veal, Assistant Secretary, and A. J. Underwood, of the Society headquarters, were among the guests. Besides Section members and friends, members of the American Society of Mechanical Engineers, American Society for Heat Treating, the Indianapolis Automobile Trade Association and the Indiana flying fraternity were in the large and interested audience.

Outing to West Point

Chartered Steamer Transports Met Section Army up Hudson for Military Academy Inspection

IT WAS "Toot! Toot! All Aboard! Next stop United States Military Academy" for Metropolitan Section on Tuesday, Sept. 9. An all-day outing and boat ride on the Hudson River to the Army reservation at West Point, N. Y., was the opening sally of the Section's 1930-1931 campaign.

In addition to the "ladies' auxiliary," headed by Miss Judy McCormick, about 150 officers and men, not to mention horses, of the S.A.E. army, marched aboard the specially chartered Day Line steamer Chauncey M. Depew before the gang-plank was taken in promptly at 10:30 a.m. Those on hand before sailing time had opportunity at the dock to inspect the recently announced free-wheeling Studebaker that will be the subject of discussion at the next Met Section meeting, and also the new Buick eight and a V-16 Cadillac. The American Austin, scheduled for an appearance, was inadvertently mislaid and couldn't be found up to the hour of departure.

Officers Go into Action

Early arrivals at the pier included "General" Austin M. Wolf, Section Chairman, and Assistant General (Manager) C. B. Veal, who hove into sight carrying a mysterious box about the size of a freight car, together with a motion-picture camera that soon went into action on all fronts. "Captain" Sid Dresser arrived in ample time to assume command of the horse marines but was taking no chances and telephoned ahead to hold the boat if necessary. "Lieutenant" Vance Howe was in charge of the heavy artillery. As soon as the 12-mile limit was passed, it was he who ably directed maneuvers of the galloping dominoes as chief of staff for Captain Dresser. In other words, the horse-race deck games contained in Mr. Veal's mysterious box proved a most popular diversion on the trip up the river. Clear and bright weather helped to make the 3-hr. sail along the beautiful valley of the Hudson a delightful one.

Luncheon was served on board about noon. Soon the Bear Mountain Bridge, a boon to motorists, was sighted and passed, and shortly thereafter the battlements and turrets of the Military Academy came into sight. Here the party disembarked to be met by Lieut.-Col. Whipple, Adjutant, and other officers of the Commandant's staff, who had made arrangements for inspection of the Academy buildings and equipment. The Ordnance Museum, established in 1854, was visited first. Here were seen models of armament from all over the world, together with many battle trophies collected from expeditions of the Civil, Mexican, Spanish and World Wars.

Impressed by Chapel and Skillets

From the museum, the members proceeded to the impressive new chapel which, from its commanding site high on the hillside, overlooks the reservation and many miles of the valley.

On the way, it happened that a group of S.A.E. stragglers was unable to persuade the officer of the guard that they were following military guides across forbidden ground, with the result that they were forced to detour, much to the amusement of the advance section.

The new mess hall was visited next, and many were the "Ohs" and "Ahs" emanating from the womenfolk as they viewed the 5-ft. skillets and sniffed the bubbling soup cauldrons.

By 3 o'clock, the Met Section army was glad to seek the parade-ground benches to watch the cadets in battalion drill and athletic events, followed later by dress parade, a ceremony dating back to 1799.

Sunset Gun Sounds Dinner Call

With the firing of the evening gun, thoughts turned to the dinner awaiting at Hotel Thayer, although the Post Garage, with its transport equipment, was open to view by those interested. Regret was expressed that the combined tank and armored car being built by J. Walter Christie was not completed in time to be demonstrated, as had been expected.

After an excellent dinner, the party again boarded the Chauncey M. Depew for the return to New York City. There were deck games until dark, then card games and dancing, together with some excitement and much smoke when someone mistook a scrapbasket for an ashtray. For those on deck, the full moon rising over the hills soon flooded the valley in its silvery brilliance.

Among many who enjoyed the outing were A. F. Shore, of the Shore Instrument Co.; A. C. Bergmann, of Bumpers, Inc., and Mrs. Bergmann; W. E. John, formerly identified with the Buffalo Section; W. H. Ahrens, A. E. Hutt, and young Jim Poole, the inveterate photographer.

For the October Meeting, the Metropolitan Section announces a paper by Delmar G. Roos, chief engineer of the Studebaker Corp., on Free Wheeling. The meeting will be held on Thursday, Oct. 16, at the A. W. A. Clubhouse, 357 West 57th Street, New York City, and will be preceded by a dinner served promptly at 6:30 p.m.

East Meets West

In recent years the Society's activities on the Pacific Coast have increased very greatly. Members in the Far Western States are very much interested in eastern automotive affairs but cannot always follow them readily. Personal acquaintance with the key members on the West Coast or a willingness to speak informally for 10 or 15 min. at West Coast Section meetings are two ways of bringing the East and the West together for mutual pleasure and benefit. If members contemplating western trips, who would like to make contacts with the western members and Sections, will forward their itinerary to the Society's Director of Section Activities, 29 West 39th Street, New York City, such information will be made available to the officers and key members of the Pacific Coast Sections.

Brakes Hold Canadians' Interest

Dr. Stanley Tells Section Members of Brake and Lining Improvements

THE first meeting of the season of the Canadian Section, held at the Royal York Hotel, Toronto, on Wednesday, Sept. 17, drew together a large number of members and their friends who are interested in the subject of automotive brake-design and maintenance, upon which an excellent address was given by Dr. F. C. Stanley, chief engineer of the Raybestos division of Raybestos-Manhattan, Inc., Bridgeport, Conn.

The new Chairman of the Section, A. S. McArthur, of the Toronto Transportation Commission, presided, and the meeting endorsed the following committee chairmen: — Entertainment, R. H. Combs; Membership, A. N. Bentley; papers, F. N. Horton; Publicity, Warren Hastings. It was decided to hold meetings on the third Wednesday in each month.

Easy on Women's Feet

Dr. Stanley, in introducing his subject, spoke of the increased demand for effective and easy braking because of the large number of women automobile drivers. Reduction of pedal effort was achieved through the self-actuating factor of the brake-shoe and the so-called servo action by which the braking effort of one shoe tends to increase pressure between the drum and the lining on another shoe. Improvements in design, he said, are chiefly concerned with reduction of frictional losses in application, the prevention of distortion of cross-shafts, and rendering adjustment simple and easy. The latest innovation, he said, is the Warner electric brake, which is controlled by means of the battery current energizing a solenoid, as described in the S.A.E. JOURNAL for August, p. 181. This brake is well adapted to truck-and-trailer trains.

Different makes of brake-lining were described by the speaker, who spoke of the tendency to use the more rigid, or molded, types because of their more uniform performance under all conditions, their resistance to the effect of oil and water and to compression, and their greater durability. With a known and constant coefficient of friction, it is now possible, he said, to design a brake that will give a vehicle of known weight a predetermined deceleration with any given pedal-pressure.

Suggests Standardized Canadian Lining

Alluding to Canadian conditions in the field of brake service, Dr. Stanley remarked that the Standardizing Committee in Canada is more patriotic than that in the United States, because in Canada the effort is directed toward increasing the Canadian content and effecting a saving at the same time. It is clear, he remarked, that little progress can be made in Canada in the field of brake-lining if the practice of the manufacturers in the United States is strictly followed, for the reason that so many types are used. There are 40 lining manufacturers in the United States, and only 4 in Canada. He suggested that the Canadian engineers represented on the Standardizing Committee disregard types and names of lining and ask the Canadian brake-lining manufacturers to produce a lining that will duplicate the performance of the equipment lining used on vehicles manufactured in the United States. There is little doubt of their ability to do this. There should be an added urge to Canadian production of asbestos brake-lining, he said, in the fact that Canada is the source of the fiber. It is good industrial practice to develop a country's own raw material, thereby collecting two profits instead of one.

Tendency to Abandon Asbestos

These remarks were listened to with keen interest in view of the wide tariff changes being made at Ottawa with the advent of the Conservative Government.

In reply to questions, Dr. Stanley said that asbestos constitutes at least 80 per cent of woven linings, some cotton being used in most of the yarn. The spinning of pure-asbestos yarn is difficult. It can be done but the droppings would be 90 per cent, leaving only 10-per cent production. Acting as a prophet, he said that the tendency will be to abandon the use of asbestos for heavy-duty linings. Twelve years ago a brake-lining to stand 1/10 hp. per sq. in. was all that was required, but today 3 hp. per sq. in. is demanded. At 800 deg. fahr., asbestos begins to lose its water content and consequently its fibrous character. Search is now being made for something of a fibrous character that is better, to give strength to a molded lining.

Engine Valves Studied

Northern California Section Opens 1930-1931 *Season with Dinner and Technical Session*

THE demands on internal-combustion-engine exhaust-valves have been continuously changing and may continue to change indefinitely, said Manse M. Harris, president of the Aerochrome Engine Valve Co., Ltd., in beginning the presentation of his paper at the Northern California Section meeting held at the Athens Athletic Club, Oakland, Calif., on Sept. 11. This opening meeting of the coming season was preceded by an enjoyable dinner and Edward Zeitfuchs was chairman of the technical session. The minutes of the last meeting were read and endorsed and a report of Section finances was made. The Section officers previously elected were installed and these gentlemen each made remarks along the lines of the special technical subject for which he is to be held responsible during the coming season.

Engine Exhaust-Valves Analyzed

Continuing, Mr. Harris reviewed some of the elementary aspects of engine-valve history and design, saying further that many engine-valve problems have been augmented by not using sufficient material in the head of the valve; the cross-section was too thin and did not give even the very best materials opportunity for the valve to hold its shape under the terrific strains created by heating and cooling. According to his experience, the valve should have a reasonably wide seat which aids materially in keeping the seat of the valve as well as the seat in the cylinder-head or the cylinder-block considerably cooler. He mentioned also that the use of too-heavy valve-springs invariably causes the valve-head to sink into the port seat. If the material in the valve has insufficient strength at high temperatures, it will stretch and immediately impair the engine power seriously.

Corrosion is another feature Mr. Harris mentioned which causes valve trouble. He said that the use of materials composed of elements which will eliminate either electrolytic or corrosive action is desirable. The high tensile-strength at high temperature is a vitally important problem in the selection of valve material. He then went into detail regarding the desirable characteristics of the various materials used for valves and described troubles encountered while testing for various valve defects, listing also the properties which a material for exhaust-valve use must possess.

(*Concluded on p.* 480)

Chronicle and Comment

The Cumulative Index

A CUMULATIVE Technical Index covering the publications of the Society for the 25-year period 1906 to 1929, is now being compiled. This will cover material that appeared in the S.A.E. BULLETIN and THE JOURNAL and that portion which was subsequently reprinted in the TRANSACTIONS. This material will be indexed in four ways: by authors and titles of papers, by discussers and comprehensively by subjects. Detailed information regarding this index will be found in this issue of the S.A.E. JOURNAL on p. 479.

Allotment of Section Territories

ATTENTION of Members and Affiliate Member Representatives is directed to the allotment of territories to the Sections of the Society as approved by the Council and published in this issue of the S.A.E. JOURNAL on p. 387.

Any Member or Affiliate Member Representative residing in the territory of any Section who is in good standing through the payment of his annual dues is thereby continued or made a member of that Section. Many Members living in such territories who formerly had not joined a Section will therefore become members of a Section upon payment of their annual dues to the Society.

These members are invited to note the Sections with which they will be affiliated and, in event of failing to receive notices of monthly meetings of the Section, to notify the Secretary of the Section. Each such member is entitled to vote and to exercise the other rights of Section members at its meetings, and his attendance and participation at meetings is greatly desired.

Members and Affiliate Member Representatives who do not live in the territory of any Section may become members of a Section upon request when paying their annual dues to the Society or thereafter and are entitled to the enjoyment of all the benefits of Section membership.

The Sixth International Road Congress

BEGINNING Oct. 6, the Sixth International Congress of the Permanent International Association of Road Congresses will be in session for six days in the City of Washington. This will be the first Congress held outside of Europe, and is to be held here at the invitation of the United States Government. The S.A.E. is a member of the Congress through the full membership of the Highways Research Subcommittee, with the Research Manager as its representative. T. Warren Allen, chief of the Division of Management of the Bureau of Public Roads, who represents the American Organizing Commission, will conduct a large group of European delegates to this Country on the steamship George Washington, due in New York City on Oct. 4.

Roy D. Chapin, a member of the S.A.E., a former president of the National Automobile Chamber of Commerce and chairman of the N.A.C.C. Highways Committee, heads the American Organizing Commission, of which A. J. Brosseau and H. H. Rice, also members of the Society, are other members. Mr. Brosseau, who is vice-president of the Chamber of Commerce of the United States, represents that body on the Commission, and Mr. Rice, who was chariman of the First Pan-American Congress of Highways and a member of the Fifth International Road Congress at Seville, Spain, and of the Second Pan-American Congress of Highways at Rio de Janeiro, represents the Highway Education Board on the American Organizing Commission.

In connection with the Congress, the American Road Builders' Association has completed arrangements for an exhibition of road-construction and maintenance equipment and materials in the Washington Auditorium, and special outdoor demonstrations of road-building and repairing methods will be given daily for the benefit of the delegates from 60 nations.

Following the close of the Congress, many of the delegates will participate in a series of three highway-inspection tours arranged by the Highway Education Board, which issued 300 invitations to the official and other delegates. Society members who are on this board are Roy D. Chapin, J. Walter Drake and H. H. Rice. The last named is Chairman of the Committee on arrangements for the tours.

Two Sides with but a Single View

LIKE most questions, the problem of employment has two sides. Unlike many questions, however, these two sides are different only in their approach to the matter; they are remarkably unified in their view of it and are splendidly harmonious in their aim.

The employer needs a man and seeks him. The man is eager to be sought and found. The Society desires to help both sides to achieve the end toward which they are working.

Whether your interest in the question is practical or academic, you will probably wish to read the brief discussion of the problem and the Society's part in it printed in this issue of THE JOURNAL on p. 495.

S.A.E. Office to Close at 12 M. Saturdays

AT ITS MEETING in Cleveland on Sept. 10, the Council voted to authorize the closing of the headquarters of the Society in New York City at 12 o'clock noon throughout the year. Heretofore the office has closed at 1 p. m. on Saturdays except during July and August, when it closed at 12 o'clock. The Council's authorization was made effective in September, thereby continuing the noon closing.

The Operator's Airplane and Engine Requirements

E. P. LOTT

W. L. SMITH

Detroit Aeronautic Meeting Paper

By E. P. Lott[1] and W. L. Smith[2]

CAUSES of troubles and expense to air-transport companies in their airplanes are dealt with comprehensively by the operations manager and a division superintendent of the National Air Transport. Commercial operation is asserted to be the proving ground for the products of both airplane and airplane-engine manufacturers, and four reasons given for this are (*a*) lack of understanding between the manufacturer and the purchaser as to precisely what is required of the airplane purchased, (*b*) inability of the manufacturer to deliver a product equal to his anticipation, (*c*) inability of the operator properly to use and care for the equipment furnished, and (*d*) the varied and opposed uses to which different operators must put their equipment.

Detailed and valuable information is given regarding the parts that give trouble and what should be done to avoid it. Reliability and ease of maintenance are emphasized as major needs of the operator, about 22 per cent of whose total expense is for labor and parts to keep the airplanes in the air. Designers and manufacturers' service managers are urged to get out into the field and become familiar with operating conditions and service requirements. Closer cooperation between airplane and engine manufacturers and between both of these and the operators is also urged.

More consideration should be given to engine durability than to weight, horsepower and fuel consumption. Airplane and accessory manufacturers are recommended to make more use of the S.A.E. HANDBOOK, and operators are advised to get together and agree upon the type of fittings they should use for plumbing installations.

The extended discussion relates in large part to what should be the cruising engine-speed and whether the engine output should be rated at full or part throttle. Misunderstanding and difficulty in learning the exact causes of complaints are attributed to failure of operators to designate parts by their correct names and to lack of complete information of operating conditions by the suppliers of equipment.

Periods between overhauls are said to vary with different operators from 200 to 750 hr., apparently with satisfactory results in each case, and so many factors enter into the matter that great difficulty is experienced in analyzing the causes for the wide variation.

AIR-TRANSPORT operation is unfortunately the proving ground for the products of both the airplane manufacturer and the airplane-engine manufacturer engaged in building equipment for use in this branch of the aircraft industry. The word "unfortunately" is used because this duty is thrust upon us in order to get from our equipment the service which we, as purchasers, should expect to find built into it when delivered to us. In groping about for reasons for this fact, we find several possibilities, namely:

(1) A lack of proper understanding between the manufacturer and the purchaser as to just what is required of the airplane being purchased

(2) A lack of ability of the manufacturer to deliver what he fondly hopes he will when he obligates himself to do the job, including improper appreciation of the importance of details by the designer of both the airplane and the engine

Other reasons are:

(1) A lack of ability of the operator properly to use and care for the equipment furnished

(2) The varied uses to which different operators must put their equipment, many of the uses containing factors opposed to one another.

Part of this paper will be confined to a discussion of these possibilities, some of which are chargeable to the manufacturer and some to the operator.

Manufacturers' and Operators' Responsibilities

Until an operator can go into the open market and buy airplanes exactly suited to his needs, as it is now possible to do in the automobile industry, he must meet with the manufacturer and decide on certain specifications. It is difficult to write ease of maintenance and durability, which are two of the prime operating necessities, into specifications without making them so complete and detailed that it would amount to the ship being designed by the operator and built by the manufacturer. This would be putting the shoe on the wrong foot, because no operator could afford to finance the designing of an airplane for the quantities he alone would need. This is definitely the responsibility of the manufacturer for all time. However, the two can get together so that the many details that an operator has found from experience must be considered carefully may be taken care of. We believe that it is vitally necessary for the designer, or the individual in his engineering department who is charged with the particu-

[1] M.S.A.E.—Manager of operations, National Air Transport, Inc., Chicago.

[2] A.S.A.E.—Superintendent, eastern division, National Air Transport, Inc., Cleveland

lar project, to spend a short time in the field in personal contact with the day-to-day work of the operator, including the overhaul and major-repair department, to gain an insight into the problem that no amount of correspondence and conferences could give him. This would serve also to help round out the practical experience side of the engineer's education, which side our experience shows is very undeveloped in many cases.

The next possibility is concerned again with misunderstanding to some extent. An operator requires a completely equipped airplane to perform a certain service. It must have landing-lights, flares, radio, brakes, adequate fuel-tankage and many other small items, each of which represents some weight and in many cases a direct decrease in speed. In other words, he wants the equivalent of a completely equipped automobile, whereas the manufacturer, in figuring the performance of a proposed design, often neglects the equipment and delivers an airplane that is equivalent to the automobile of 20 years ago, which was sold without headlights, top, horn and so on. The only major difference is that the equipment put on the car did not affect its performance adversely to anything like the extent that it does in an airplane.

Ship No. 27.

To: Superintendent of Overhaul and Repair

Nov. 18, 1929.

From: Assistant Superintendent of Overhaul and Repair

Subject: Repair Job. No. 1061-E. 3477-A, 3491-A. Douglas Ship No. 27. Engine No. 32 removed after 262.05 hr. Engine No. 49 installed. Ship time since last overhaul, 1601.01 hr.

1. Radiator flushed and checked for leaks
2. All new gas, oil and water hose installed
3. Gravity fuel-line insulated at left front cabane strut
4. C-5 fuel-pump overhauled
5. Bronze seated B-1 relief valve installed
6. New starter-shaft bolt installed
7. All landing-gear bolt-holes rebushed
8. Both oleo legs repacked
9. Two reconditioned axles installed. (Drilled and packed for self-oiling)
10. New brake-control cables made up and installed
11. New wheel bushings installed
12. Fuselage brace-wires station 8 tightened
13. Engine torque-control assembly rebushed
14. Control-stick assembly checked
15. Exhaust pipes and heater manifold painted
16. New left lower aileron installed
17. All aileron hinge-bearing holes rebushed
18. Rudder-bar pedestal rebushed
19. Rudder bearings refitted
20. New elevator-control pulleys installed
21. Elevator bearings refitted
22. Stabilizer adjustment-post overhauled
23. Flares drop-tested and bottom covers greased
24. Experimental cockpit heater installed
25. All necessary cowl repairs made
26. Felt strip installed between cockpit cowl and fuselage
27. Mail-pit rain troughs installed
28. Ship refueled after test
29. Engine checked after test
30. Battery cables treated
31. Gas and oil lines checked for defects
32. New safety-belt and seat-attachment fittings installed
33. Ship inspected and O.K.'d by P. Rickel
34. Test flown by Pilot Burnside (1 hr., 30 min.)
35. Ship accepted by Operations Inspector J. Baltrusis

INSTRUMENT REPORT, Job No. 555-I

1. Instrument panel No. 1 removed
2. Compass changed, account sticking
3. Turn indicator overhauled; new fork assembly
4. Turn-indicator venturi straightened and lines cleaned
5. Air-speed indicator checked, O.K.
6. Air-speed lines cleaned and connections renewed
7. Tachometer checked, O.K.
8. Altimeter checked, O.K. Barometer scale reset
9. Rate of climb checked, O.K. Stop installed
10. Hygrometer changed for new one and shock-absorber felt installed
11. All instruments numbered
12. Compass compensated

R. Dehority, Assistant Superintendent,
Overhaul and Repair

FIG. 1—TYPICAL N.A.T. REPAIR-JOB REPORT, SHOWING NUMEROUS ITEMS GIVEN ATTENTION

As to the operator's responsibility to keep the equipment in proper shape, much may be said on both sides. It is necessary only to note the different standards to which operators maintain their equipment to see what a difference care makes. Manufacturers can do much in properly instructing operators in the use of their products, and to do so is money well spent, because, if a new piece of equipment gets off on the wrong foot in an operating organization, a great deal of very good service is required to live it down, and the manufacturer, as well as the operator, suffers in the meantime. By having liaison engineers in the field, the manufacturer will learn as much about a new piece of equipment as will the purchaser at a time when this information is of the most value to both.

Ease of Maintenance Important

Fortunately, one or two of the airplane-engine manufacturers have appreciated the need for the proper servicing of their products and, in addition to having their own men in the field, have established schools in their factories for air-transport-operation employes. If these schools are properly conducted, the engine manufacturer should have no fear that his product is not receiving the proper service in daily operations.

Ease of maintenance is one of the things the operator needs most, because about 22 cents out of every dollar he spends now goes for labor and parts to keep his ships in the air. As far as some manufacturers are concerned, "ease of maintenance" exists only as a phrase in the beautifully composed literature regarding their products.

The different conditions under which most operators have to function make it hard for a manufacturer to adapt one basic model to varied extremes. However, this can be done without an appreciable sacrifice if sufficient attention is paid to the details. In our operations, we aim to fly ships in 250-hr. periods; that is, when a ship is sent out of our shop and placed in operation, we expect all of its component parts to give trouble-free service, at least until time for the next engine-change. We have had to make many expensive changes in our equipment to attain this goal and still the work sheet on our average engine-change contains 40 items, many of them small but nevertheless requiring inspection and replacement. It is significant that, although we operate numbers of three different makes of airplane, the total number of items for each make is about the same, although the items themselves vary greatly between makes. The items in an actual repair job are shown in Fig. 1. It may be also mentioned that the earliest designed airplane requires the least service now, presumably because it has gone through the most development in our service.

Some Sources of Trouble and Expense

Some of the things which are most troublesome because of the time and money involved in their maintenance are as follows:

Engine Cowling.—This is a source of much grief, for three reasons: first, because it cracks; next, because it pulls loose from its fastenings and wears itself apart; and, third, because it is generally so difficult to remove and replace that, to do the job he is paid for, a mechanic generally spends as much time getting to the job as he does in making the inspection or repair.

The remedy lies in hinging the cowling at the top or

one side and using hood latches on the other side, all similar to automobile practice. Where there must be movement between one cowl-support, the cowl and another support, rawhide lacing should be provided to keep the cowl from rubbing the support, again as on an automobile. The cowl should not be fastened rigidly to two separate pieces of support both of which move, because either the fastenings will come loose or the cowling will crack. Cracking may also be caused by flutter in the air due to lack of stiffness within the cowling itself. Some manufacturers make the mistake of fastening some cowl supports to the fuselage structure and other parts to the engine. Relative movement between the two then proceeds to ruin the cowling, if it has been fastened rigidly to both.

Engine Mounts.—There is great need for shock-absorbing units in the engine mounts to prevent any vibration that may be present in the engine from being transmitted to the rest of the airplane. This has been satisfactorily done in most automobiles and in some airplanes, but its universal application in airplanes has not as yet been accomplished. This is necessary, not only to lengthen the life of the airplane and its parts, but also for the comfort of the passengers.

Engine Installation.—From our experience the space between the rear of the engine and the fire wall might well be called "No Man's Land," because a look at many airplanes, particularly those with engines of more than 400 hp., will reveal that this space is generally filled with pipes and wires running in all directions and all tangled up. This has happened because the plumbing and wiring are often done as an afterthought in the shop instead of in the drafting room with a complete mock-up by one who is competent to lay out such systems. They require careful study if the job is to be done properly.

Fuel Systems Too Complicated

Fuel System.—This is much too complicated. There are too many odd lengths of fuel line, too many hose connections and too much chance of failure. The fuel system should be built as a unit, attached to the engine, and operated by remote control, as far as this is necessary. It should be designed with no pockets in the lines in which water can collect and freeze. It should also be arranged so that the fuel will not boil in the lines in warm weather, thereby causing vapor lock and engine failure.

Satisfactory means should be provided to absorb vibration in the fuel lines between the engine and the rest of the plane. This is now done by using many hose connections, each one of which is a potential source of trouble. A reliable fuel-gage should be available and there should be one of these for each fuel tank. It would be very desirable in the interest of economy to have a reliable flow-meter connected into the fuel line so that the pilot could know at just what rate the engine was burning fuel. He could then adjust the mixture control much more intelligently, in addition to having a further check on his fuel supply.

Many times the fuel system itself is the cause of considerable trouble because of inherent defects in its design. We have evolved a system, out of the remains of many, which gives us very little trouble in service, and in which trouble, when it develops, is almost always in one of two places. These are the pressure relief-valve or bypass and the wabble pump. This system is shown in the schematic diagram in Fig. 2.

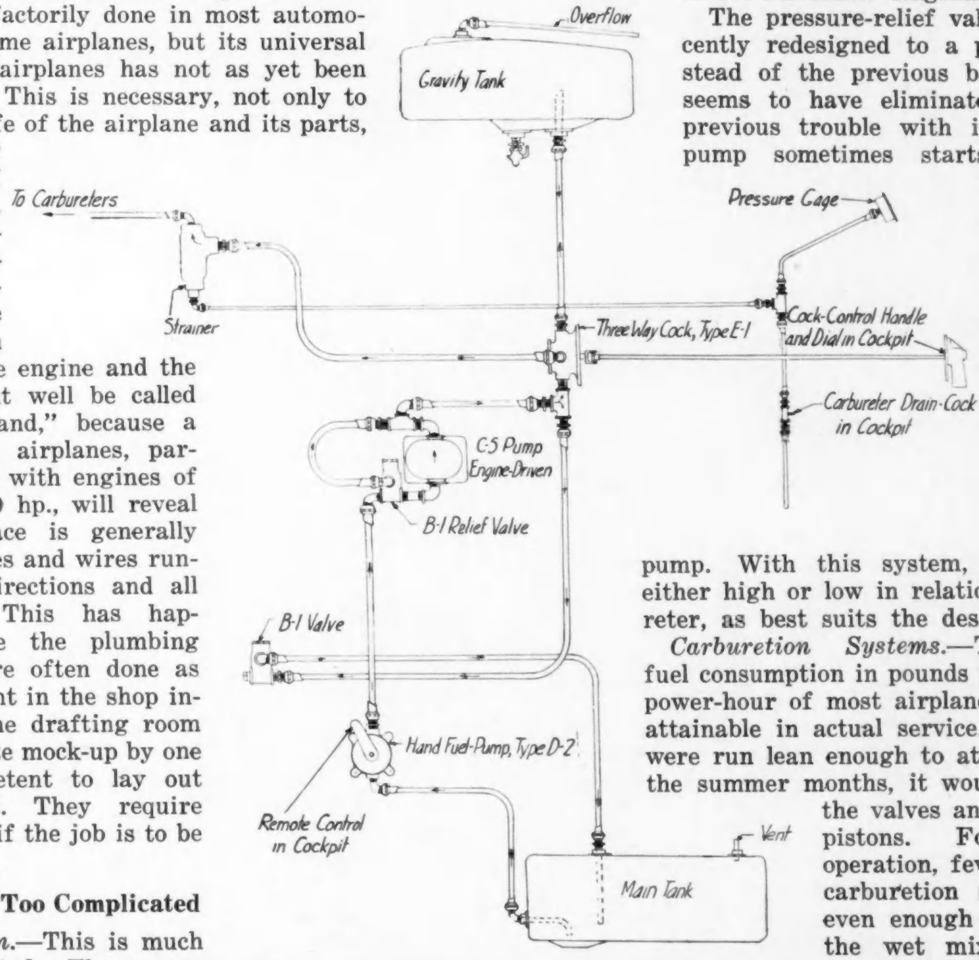

FIG. 2—SCHEMATIC DIAGRAM OF FUEL SYSTEM EVOLVED FROM THE REMAINS OF MANY BY THE NATIONAL AIR TRANSPORT REPAIR BASE

This System Gives Very Little Trouble, and When It Occurs It Is Usually in One of Two Places

The pressure-relief valve we have recently redesigned to a poppet type instead of the previous ball type, which seems to have eliminated entirely the previous trouble with it. The wabble pump sometimes starts sucking air through the packing, which is a service problem. The gasoline is by-passed from the line between the pump and carbureter directly back to the tank, not to the suction side of the pump. With this system, tanks may be either high or low in relation to the carbureter, as best suits the designer's problem.

Carburetion Systems.—The advertised fuel consumption in pounds per brake horsepower-hour of most airplane engines is not attainable in actual service. If the engine were run lean enough to attain this during the summer months, it would usually burn the valves and sometimes the pistons. For cold-weather operation, few of the present carburetion systems provide even enough distribution for the wet mixtures that are usually in the inlet manifolds to make possible low fuel-consumption without danger of starving one cylinder, with resultant damage to it. This latter feature is particularly true of radial engines.

Magnetos.—These give us very little service trouble and seem to be the most highly developed of our accessories. However, a good look at the standards in the S.A.E. HANDBOOK in connection with threads would help considerably in the matter of standardization.

Wiring System.—The electrical wiring system on a

modern transport plane equipped with a generator, starter, landing, navigation and instrument lights, and radio is becoming very complicated compared with previous aeronautic requirements. It is strongly urged that light, rigid conduit, fundamentally like standard electrical practice in buildings, be provided in all new equipment. This has already been used by one manufacturer and looks like a big forward step.

Control Systems Shake to Pieces

Control Systems.—These are another cause of considerable trouble because their different joints wear out so rapidly, not because of the demands imposed by their frequent use, but because they literally shake themselves to pieces. For instance, clevis pins which are not subjected to a definite load at all times frequently enlarge the clevis hole to such an extent that the system becomes very loose-jointed and requires replacement just because the parts jiggle around in flight. Completely enclosed ball-bearings will do much to help this in many places. This applies also to spark and throttle controls.

Wheel Bushings.—These are another source of grief, occasioned mostly by the universal use of brakes. Previous to their use, the clearance between the axle and bushing was of little real consequence as long as the wheel did not bind or come off, but very close tolerances must be maintained now, so that the brakes and drum will remain concentric. This is necessary to assure proper brake operation. Ball or roller-bearing wheels seem to be the answer and are available at least in some sizes, but still they have appeared commercially on a very few airplanes other than the Ford Trimotor, which has always had them.

Landing Gears.—These do not give the operator much trouble these days, with the exception of the bushings. The strut bushings are not yet of sufficient size to give us trouble-free service, and in most cases the attachment bolts bear directly on the strut fittings with no replaceable bushing of any kind. This means that, besides the rapid wear due to insufficient area and improper lubrication facilities, there is added replacement cost to bring the clearance to standard. All fittings wherein movement must take place should be capable of being easily rebushed.

Tail Skids.—Skids and their anchorages are still weak and we must strengthen the skids soon after we receive new ships. But this does not eliminate the trouble because, when the skids are made strong enough, the anchorage pulls out and we have to start all over again. In our service, a tail-skid assembly that will not resist frozen ruts is too weak. The tail-wheel may help this considerably. However, its use by us is dependent on much better brakes than we now have, which in turn depends on ball or roller bearings for the wheels.

Cockpit Design, Heating and Ventilation

Cockpits.—Much more care should be exercised in laying out the cockpits. So many gadgets are used at different times by our pilots that the inside of our cockpits looks somewhat like an organ keyboard that has grown up without guidance from any one person (See Fig. 3). We believe that the design of the pilot's cockpit should begin as a box without a lid, then the different controls should be led to it with only the part handled by the pilot coming through inside. The fuselage covering outside of this so-called box should be removable so that the rods, joints and other parts of the control system can be readily inspected and serviced. This will make the compartment much less crowded and more easily cleaned by the service crews. In addition, it will simplify the problem of properly heating it because there will be less opportunity for heat to escape through the various small openings.

The cockpit heating problem is a serious one to which very little careful thought is given. Provision should be made so that the cockpit temperature will always be above 45 deg. fahr., because a pilot sitting in one position for 5 or 6 hr. at sub-zero temperatures, as is often the case in winter, cannot keep comfortably warm without so much clothing on that it is very difficult if not impossible to move his arms or legs enough to do his work properly.

Closely linked with this problem is that of cockpit ventilators for use in the summer. The layer of air next to the fuselage of most transport airplanes holds the warm air from the engine compartment as well as the gases from the engine breather. These eddy around behind the windshield or through the small openings and make the cockpit very uncomfortable for pilots in the warm weather, particularly where they sit with the sun beating down on them with the thermometer at 90 deg. or so. An ample supply of fresh air should be capable of introduction into the cockpit to relieve this condition, and this supply should be under the pilot's control at all times. It may be interconnected with the heater for simplification.

Exacting Demands on Powerplants

Powerplants.—Because the airplane is dependent upon its powerplant to keep it in the air, this is the most important part of the airplane, if any part may be called most important. The powerplant must function properly through sunshine and rain, through sleet and snow. With the aid of radio and increasingly better airplane flying-instruments, we are slowly approaching the goal of regular operation on schedule, regardless of the weather conditions. If the engine is to function satisfactorily under all of these conditions, some radical changes must be made in its design and in that of its accessories.

The relative humidity of the air will vary from 0 to 100 per cent, and its temperature will vary from −50 to +120 deg. fahr. The carbureter system must take air under any of these conditions, mix it with the right quantity of fuel and deliver a uniform mixture to all cylinders. If frozen moisture is present in the air, enough heat must be applied in front of the carbureter to melt all of this frost, and enough heat must be applied to or behind the carbureter to vaporize the fuel and keep this moisture above the freezing point. We have at times measured a drop of 90 deg. between the carbureter air-intake and air-outlet, yet no provision is made in the design of the engine itself, where there is so much heat to dissipate, for absorbing this loss without piping the exhaust in through the engine compartment to a hot-spot and to a warm-air horn. During the World War, heated air was taken from around the crankcase bearings on a foreign engine through passages in the case and thence to the carbureter. This, in addition, helped to cool the oil. However, all this progress seems to have been forgotten, as no such carburetion system has been built on any modern airplane engine by the manufacturer.

Our carbureters give us some mechanical trouble because they have a tendency to shake themselves apart at times, and insufficient care is taken by the manufacturer to see that the screws can be securely locked.

Moisture is present in the air to some extent at all times, and it will condense on the inside of the carbureter bowl and form drops which cannot get through the small jets used in airplane carbureters. If this water could go through the engine, it would have a very slight effect upon the operation of the engine, but it can and does stop the engine when it plugs the jets of the carbureter. Either carbureters must be redesigned so that small particles of water and dirt can go through the jets or else means must be provided for removing these particles from the jets, when they do appear, while the airplane is in flight. In the same way, it should be possible to drain all of the strainers in the fuel lines while the plane is in flight.

The carbureter air-intake on most radial engines is on the bottom of the engine, where it will pick up a great deal of dirt from the flying-field in the summer-time and in the winter-time choke itself with snow whenever there is any on the ground. The introduction of the downdraft carbureter makes it possible to put this air scoop on top of the engine, where it belongs, and manufacturers should lose no time in doing this. For the present, the operator is faced with the necessity of providing extra piping and extra weight to accomplish this necessary result.

Oiling Systems Need Revamping

The present oiling systems on engines need to be thoroughly revamped so that the oil can be warmed quickly and maintained at the right temperature in sub-zero weather without removing it from the plane. Likewise, this same system should keep the oil cooled in the hottest weather. At present there are too many pipes and fittings and too much juggling of these to accommodate the outside-air temperatures. Since we desire the unit to function with as little attention as possible for at least 250 hr. and more as time goes on, the lubrication system should be complete and entirely automatic, and all the moving parts should be enclosed in dust and oil-tight housings. It may be surprising to know that it takes just as long for us to properly service the valve gear on the modern radial engine as on our old Liberty engines having the springs and rocker-arms out in the open, and we have to do it just as often. Therefore, little progress has been made in this particular item since the war, with the possible exception of less dust on the parts and consequently less wear; and this gain is very slight, because there seem to be many manufacturers of modern engines whose valve gears are yet far from completely enclosed. Much oil leaks from these partly enclosed rocker-boxes back on the cowling and windshields, necessitating further expense to keep them clean.

There is room for much improvement in temperature-indicating systems, particularly on air-cooled engines. It should be possible for the pilot to easily secure a much more accurate indication of operating temperatures than by the present method of reading the oil temperature only. A suggested means is thermocouples buried in the head and flange of the hottest cylinder, in the inlet manifold above the carbureter, in the scoop below the carbureter, in the intake oil-line, in the outlet oil-line and in the outside air. Then, by switching around, the pilot could read all of the temperatures without as many thermometers as we now have to have and be better able to adjust the cowling properly in flight.

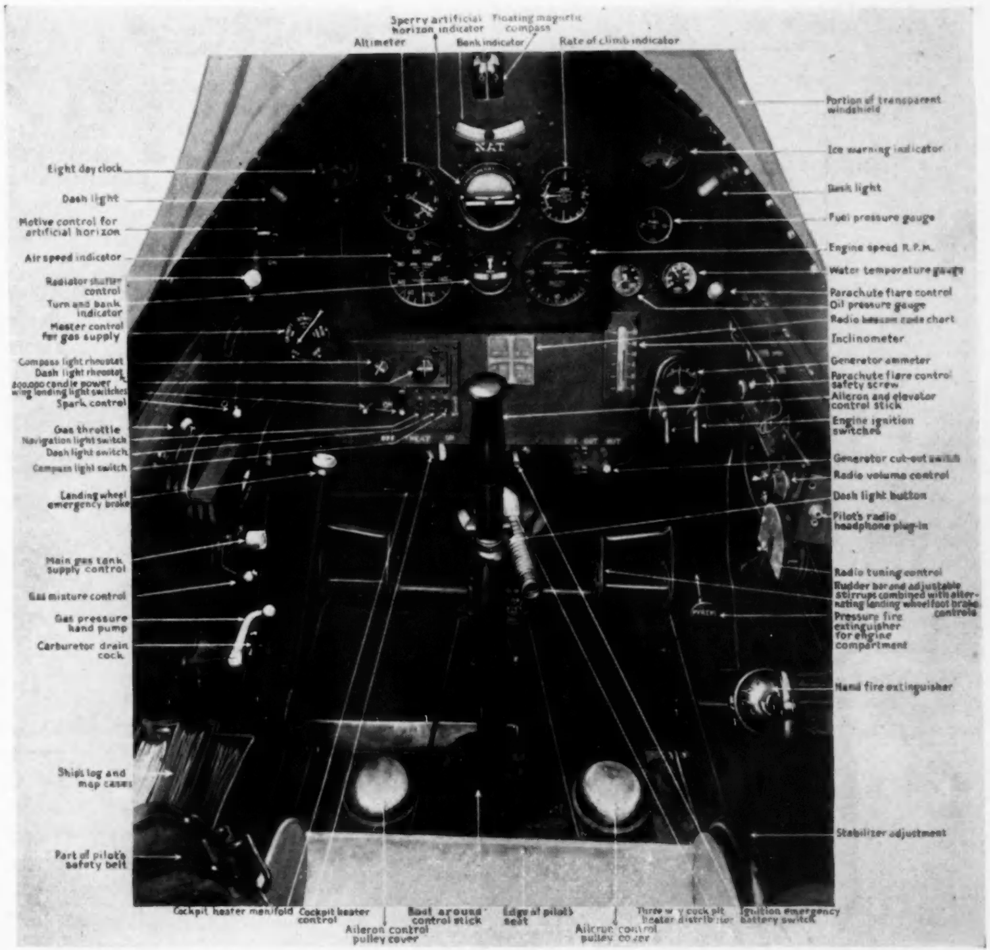

FIG. 3—PILOT'S COCKPIT OF AN N. A. T. MAIL AND EXPRESS AIRPLANE
Note that There Are More than 40 Instruments and Controls To Engage the Pilot's Attention

On liquid-cooled installations, care should be exercised to be sure that the radiator is properly supported so that it will not be twisted or strained because of vibration or other cause. Suitable shock-absorbers, such as soft rubber pads, should insulate it entirely from the rest of the structure.

Shutters, whether in the cowling of air-cooled engines or in front of radiators, should have large bear-

ings with replaceable bushings. They should be so mounted that the possibility of flutter is eliminated, to prevent them from wearing themselves out.

Engine Builder Should Provide Shielding

Radio Shielding.—The rapid introduction of aircraft radio that is now taking place makes necessary the bonding together of all the metal parts of the airplane and subduing and shielding the high-frequency harmonics from the electrical circuits of the plane. This work is all being done now by the air-transport operators at considerable expense. Because radio is now a very necessary part of the equipment of every transport plane, it becomes the manufacturers' responsibility to see that this is done in the process of manufacture. This means filters for the generators and shielding for all electrical circuits, including the ignition circuits and the spark-plugs.

The introduction of shields on the outside of insulated wires makes it necessary to increase the amount of insulation, since it was designed to insulate wires from only occasional conductors on the other side of the insulation. Because this shielding adds both weight and expense, considerable thought needs to be given to the shortening of all of these wires as much as possible by providing mechanical remote control. This shielding of the high-tension ignition wires, and the spark-plugs in particular, will also protect these wires from oil and moisture. Such protection is not provided at present and many failures result from these causes. It is questionable how long the present radial engines will fly through heavy rain or snow with the spark-plugs and high-tension leads exposed as they now are.

The matter of cylinder-wall temperature control on a radial engine, coupled with that of head resistance, is a serious one. Considerable research work has been done with various types of cowling, but none of these has as yet proved thoroughly satisfactory in daily operation. This is true, not only from the angles of correct heat control and reduction of head resistance, but also from the angle of maintenance. Where the pilot is located directly behind an engine, the problem of providing him with sufficient visibility is also one that has not been satisfactorily solved in most airplanes. The addition of any cowling usually makes this problem worse instead of better.

Most engine manufacturers apparently consider only weight, horsepower and fuel consumption. More consideration should be given to durability.

More use of the S.A.E. HANDBOOK could be made by airplane and accessory manufacturers.

The operators could well afford to get together themselves and decide upon the type of pipe fittings they should use for plumbing installations and instrument connections, as well as standard cockpit-layouts and many other items which probably tend to drive the manufacturer crazy when he is trying to please us.

THE DISCUSSION

CHAIRMAN EDWARD P. WARNER[3]:—The problems of air transportation and of aerial operation in general are numerous and diversified, but none of them is more important than the establishment of a continuously harmonious understanding and cooperation between the operator and the manufacturer of equipment. There are a great many advantages in having the airplane structure and the powerplant come from different factories. The problems of design and construction of the plane and the engine are essentially different and they have grown up on separate although parallel lines as two more or less distinct industries. But against those advantages is the one disadvantage that it becomes peculiarly easy for the airplane and engine people to fancy themselves as standing on opposite sides of an impenetrable barrier making faces at each other, and each proclaiming to the world that the other is incompetent.

If any reconciling factor is necessary, the operator should provide the reconciliation, because it makes no difference to him what breaks down; whether the airplane or the engine goes wrong, he is out of luck just the same. We have fallen into the habit in the Society of calling on the operators every now and then to tell what is wrong with the manufacturer. Several times in the past we have been able to call on the high operating officials of the National Air Transport, and the results have always been interesting. The present paper covers an extraordinary range of subjects, with correspondingly broad opportunity for discussion.

[3] M.S.A.E.—Editor, *Aviation*, New York City.

[4] M.S.A.E.—Assistant engineer, Curtiss Aeroplane & Motor Co., Buffalo.

MARSDEN WARE[4]:—I feel that much is to be done by the operators in helping to get better service from the aircraft manufacturer or the aircraft-engine manufacturer. Mr. Lott said that some of the manufacturers are setting up liaison organizations that are getting into contact with the operators, finding out the difficulties and correcting them within the manufacturing company. That calls for a very broad organization to cover all of the operating forces now in existence, and, while the manufacturing companies have accomplished considerable in that direction, it is hardly likely that they can cover every operator to complete satisfaction.

The point I desire to make, which probably does not apply to Mr. Lott's company or other organizations that have given careful thought to it, is that much can be done by the operators, when ordering parts and replacements or when reporting trouble, to make that trouble very clear. Some of the reports of difficulties in service and the description of parts that are desired seem somewhat humorous to the manufacturer. The engine manufacturer in most cases has given every part a special name, and he has also given each part of his engine a number. Those names and numbers are frequently ignored, and a replacement part which is needed in a hurry so as to continue operation is specified in the order by some name that is very difficult to associate with the part.

We feel that the operators should use the greatest care when ordering parts and when reporting trouble, to make clear just what that trouble is or to give the proper identification of the part. The manufacturer would appreciate that effort, because he desires, of course, to give every service possible.

A. F. WINN[5]:—Will Mr. Lott tell how he computes the time on his engine? Is it exclusively in the air, or on the ground as well?

E. P. LOTT:—It is just flight time. We pay no attention to the time the engine is on the ground. When we first started operation, we kept track of the ground time and of the air time. After the first year we found that the ground time averaged about 5 per cent and was mostly idling, so we now disregard it entirely.

J. T. HARTSON[6]:—Does the fuel consumption include idling?

MR. LOTT:—No, it does not.

Part-Throttle versus Full-Throttle Operation

HAROLD CAMINEZ[7]:—Mr. Lott has paid such particular attention to durability of the engines that it would be interesting to know his viewpoint on that phase of the subject. It has always been suggested that if we run our engines at less than full throttle we have more durability, but this cuts down airplane performance. If we want performance we have to run the engine wide open, or very nearly wide open. Considerable difference of opinion exists as to whether we should design our engines very light in weight, and therefore make it necessary to run them at part throttle at cruising speed, or should design them to stand up at full throttle for considerably longer periods.

EDWARD P. WARNER

MR. LOTT:—In our organization there is no such thing as full-throttle operation. The only time we have the throttle wide open is when taking off from the field and for the first 1000 ft. Cruising speed, to us, is four-fifths of full-throttle revolutions per minute. That is our standard speed and is the speed on which we base all of our figures.

CHAIRMAN WARNER:—That raises some questions in my own mind. The subject is one that is being discussed at numerous meetings. We had a long argument at the first National Aeronautic Conference in New York City in the fall of 1928 over the contention that, when an engine is rated at a given power, that should necessarily imply the ability to function indefinitely at that power without any probability of mechanical breakage. There exists in some quarters, however, a presumption, resulting from the long established habit of cruising at about 80 or 85 per cent of the maximum revolutions per minute, that if the engine is run at full throttle for very long it is going to fly to pieces or something serious is going to happen very soon. Some manufacturers repudiate that idea. All they will admit is that the engine will not have as long a life between overhauls if run at full speed and that the maintenance cost will be higher. Some have been reluctant to concede that any danger is involved in full-throttle operation.

I think that in some foreign countries it is habitual to operate at a substantially higher proportion of the maximum revolutions than is conventional here, especially on military airplanes.

Holding Pilots to Fixed Cruising Engine-Speed

The discussions started concern themselves also with the means of controlling and recording the adherence of the pilot to the cruising speed laid down. In the first place, is it your practice and the practice that you recommend to fix a definite cruising engine-speed and hold to that without regard to wind conditions? In at least one European country where the operating companies specialize in passenger carrying, the engine speed is varied with the wind.

In the second place, have you reason to believe that the pilots generally, on your own or any other well controlled line, follow those stipulations rather rigidly? In the third place, do you think it is desirable to have any permanent mechanical record, for the use of the shop and the maintenance department, of just how the engine is running?

For several years the practice on the Imperial Airways was, and I think it is still, to have a recording tachometer on every engine, and charts, miles in length, that came off the engine showed the exact revolutions per minute for all flying periods.

MR. LOTT:—Answering your first question, this 80 per cent of full power is wide-open operation to us. We do not increase the throttle beyond that point, but we do decrease it when we have a substantial tail wind and are appreciably ahead of schedule.

Concerning the keeping of records of the engine speed, we should like to have a recording tachometer, merely for purposes of comparison. However, the ones that are available at present are considerably heavier than we think they should be, and for that reason we have not used any.

Regarding the control of the pilots, we have reason to believe that they sometimes open the throttle too wide. However, the instructions are that it must not happen, and, if one pilot seems habitually to lean heavily on the throttle, it does not take long for that to show up, because the performances each day are comparative. Several airplanes are flying over the same course each day, and we soon learn that one man seems habitually to make higher speeds than the others. The other pilots call his attention to it even before the figures are available to us, and he will change his tactics.

Power Sacrificed at 80 Per Cent Full Throttle

MR. CAMINEZ:—The 80 per cent of full-throttle revolutions per minute is about 50 per cent of engine power. If the operators use engines only at that comparatively low power, it seems to me that they are sacrificing a good deal of engine weight and performance. It seems certain that engines can be built that will operate more than 250 hr. at much higher power rating and therefore, when the operators choose engines, they should not consider the weight per horsepower at full-throttle speed, but the weight per horsepower at the operating speed at which they are using the engines. If they are going to use it at half full-throttle speed all of the time, it seems to me that that is not very efficient.

MR. LOTT:—We shall be glad to push up the engine speed as soon as the engine will stand it.

MR. CAMINEZ:—One of the facts that are limiting

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[6] Comet Engine Co., Madison, Wis.

[7] M.S.A.E.—Engineer in charge, Cadillac Motor Car Co. Aircraft Engine Division, Detroit.

power with reliability is the fact that we do not have enough cooling; in northern latitudes air-cooled engines can be run at higher power than they can where the climate is hot.

MR. LOTT:—We have varying operating conditions to consider every day. One day the temperature may be 80 deg. fahr. in Dallas, Texas, and 30 deg. fahr. in Chicago, and we have to combat those changes in temperature with the same airplane almost daily. On the other hand, regarding this problem of running the engine at 50 per cent of full throttle when the engine speed ought to be higher, we find that if we allow our engines to run too fast we have a great deal of trouble, and we do have much trouble now. It is occasioned by the fact that the engine does not stand up under our present r.p.m. rating, and when we seem to push it we have more trouble. With the air-cooled engine we burn the head of a piston or have some other such trouble. Our only water-cooled engines are the Liberties, and as soon as a Liberty engine is pushed, all kinds of water leaks occur.

Difficult to Learn Exact Service Conditions

B. H. GILPIN[8]:—We are in constant contact with the various operators and find that there seems to be a great need today for a common language among operators that can readily be interpreted by the manufacturer. Some operators talk in our own language so that we know very definitely what kind of service they are getting from their engines. Others we do not so readily interpret; consequently it is very difficult for us to know the comparative service our engines are giving.

Most operators talk in terms of cruising speed, but due to the various propeller settings, which mean entirely different engine loads, various service results are obtained. Some operators have facilities for warming up their engines on clean fields, while others have to warm up their engines on dusty fields. Some use upper air-intakes; some do not. Some use one kind of oil and some another. The oil may be of good quality but it may not be particularly suited to the engine. Fuel is also a very important factor and probably the use of fuel with improper knock rating may account for the trouble Mr. Lott has experienced with burned piston-heads in air-cooled engines. Some run in one kind of climate and some in another; Mr. Lott said that he has to contend with all kinds of climate.

HAROLD CAMINEZ

We are endeavoring to work closely enough with operators so as to have a record of the kind of service their engines are giving and the conditions to which they are subjected. The operators are cooperating very closely with us, and I believe that before long there will be a much better understanding between the engine manufacturer and the operators so

B. H. GILPIN

that manufacturers will have full information regarding operators' requirements and the operator will better understand the proper operation and maintenance of the engines and more nearly get the service that has been built into the engine by the manufacturer.

There is the other element, of course: one manufacturer constructing the plane and another building the engine, which is making the situation very difficult for both the manufacturers and the operators. Until we are all together on a common ground, we will of course have more or less trouble in finding out what the requirements are.

CHAIRMAN WARNER:—It seems to me completely unfair to the innocent prospective user to rate an engine at a power at which it will not run without structural danger over virtually indefinite periods, that is, as long as it is running without immediate need of maintenance due to wear. The wear will inevitably be more rapid, but the engine ought to stand up at the rated power.

MR. CAMINEZ:—Mr. Lott's organization uses engines at 50 per cent of their power. On the other hand, the same make of engines that he has used have been run for considerable periods at around full throttle. The Army and Navy use the same make of engine, but do not limit it to such low power-output. The difference is that, in slow commercial airplanes, the cooling conditions are not the same as they are in military planes and on test work in the manufacturers' plants. The safe power-output of air-cooled engines is limited by the cooling conditions, and when we sell an engine and we state the power of the engine without describing the cooling conditions, we are not complete in our description.

If an airplane fitted with an air-cooled engine that is designed for military planes and that will stand up at 90 or 80 per cent of full-throttle operation for 250 hr., with an airblast of 150 or 175 m.p.h., is flown at only 110 m.p.h., we cannot expect the same reliability. Therefore, in describing engines that do not have complete control of cooling conditions, such as the fluid-cooled engines, we should state the cooling conditions for which these engines were designed. I believe that is one condition that makes rating our present aircraft engines very difficult.

Troubles in the Naval Services

LIEUT.-COMMANDER A. C. MILES[9]:—I do not think that the Navy has the same problem at all. The average cross-country trip that we take, which compares with commercial flying, is run at about 80 per cent of full throttle; the Wasp engine travels over land at about 1600 or 1650 r.p.m.

I am surprised, considering the scope of the paper, that the authors did not mention the importance of finish on metal airplanes. Possibly the reason is that the transport company's airplanes do not come into contact with salt water or because the company does not

[8] M.S.A.E.—Service manager, Pratt & Whitney Aircraft Co., Hartford, Conn.

[9] Lieutenant-Commander (C. C.) Bureau of Aeronautics, United States Navy, City of Washington.

have to contend with the thing that the Navy is continually contending with and that is the cause of most of our trouble. We find that, as aluminum alloys are used more and more in the construction of airplanes, it is necessary to finish them, even if they are to operate in Texas or Colorado or anywhere away from salt water, because it is absolutely necessary to arrest so-called intercrystalline corrosion. In the operation of seaplanes, I think that at least 50 per cent of the maintenance is in stopping the corrosion attack.

The paper by Mr. Lott and Mr. Smith amused me in a way, as it seemed like a résumé of a series of complaints that we receive from our operating squadrons and it was really very well done. They have covered the whole field, apparently, which certainly reminded me of home, but there are two or three things that could be emphasized. Regarding the wear of bushings, we found that it is much worse with the aluminum alloys than it is with steel. We are compelled to put steel bushings, probably of a stainless variety, on hinge fittings, control plugs, and in all the various places that tend to wear and shake to pieces after the airplanes have been in service for a few years.

Standardization of Parts and Fittings

One other thing I might mention is standardization of parts and fittings. The Army and the Navy have for the last several years attempted to standardize their own fittings, screws, bolts and fixtures of different kinds that go into airplanes and have, I believe, attempted to get the industry at large interested in these efforts. Mr. Warner is doing quite a bit himself along these lines in trying to promulgate what the industry and the Army and Navy are doing. A conference on the subject is to be held in May at Wright Field, and I believe that the industry at large has been invited to send representatives to cooperate with the Army and the Navy, in standardizing fittings, screw-heads, bolts, fasteners and the like so that we shall not have six or seven different kinds of parts on every airplane.

LIEUT.-COM. A. C. MILES

Mr. Ware mentioned operators' complaints and the difficulty the engine and airplane manufacturers have in understanding them. We find it to be even worse than he described. We can take airplanes from a single production order from any one company, send a squadron to the West Coast and a squadron to the East Coast, and get an entirely different series of complaints from one squadron than we do from the other. We find that the troubles that are severe and important on the West Coast are not the same troubles they have on the Atlantic Coast. The same is true of engines, and it is rather difficult for any manufacturer to determine, from reports that he gets from all over the Country, just what the difficulties are.

I think it is most important, as the paper pointed out, that the designers get out in the field and learn something about the operation of airplanes and how they fly. Both the Army and the Navy have recognized the importance of this for several years and are trying to make pilots and really good flyers out of the men who are in charge of the designing, upkeep and maintenance of airplanes. I do not think that can be emphasized too strongly.

CHAIRMAN WARNER:—Apropos of Commander Miles's remarks regarding the standardization conference, the Society is in an exceptionally fortunate position in maintaining the liaison between its standardization work on behalf of the industry and that Army-Navy conference, because J. F. Hardecker is now Chairman of the Airplane Division of the S.A.E. Standards Committee.

The Bureau of Standards is deeply involved in the questions of rating engines, of what is cruising speed, and of the conditions under which an engine runs. H. K. Cummings, of the Bureau, is conversant with everything they do down there.

Department of Commerce Engine Tests

H. K. CUMMINGS[10]:—The Bureau and the Department of Commerce would be very happy to increase the requirements now imposed on commercial engines so as to ascertain whether they will stand up for severe service at their rated speed and power when wide open. In fact, a conference with representatives of the Army and Navy at the time type-testing of commercial engines was proposed brought out the information that the Army and the Navy contemplated requiring an engine to pass a wide-open full-throttle 50-hr. endurance test, preferably non-stop. The Department of Commerce considered a similar requirement, but it did not meet with enthusiasm, and we found that neither the Army nor the Navy always insisted on that sort of a test, although they sometimes run such tests.

If engines are to be used in commercial practice largely at full throttle, they certainly should be tested under like conditions, because the test is supposed to find out if design changes are needed in the engines that operators propose to use in licensed planes in order to assure safety and reliability.

The present Department of Commerce test is very much the same as the test the Army has had for many years; namely, the engine has to run 5 hr. wide open at the rated speed designated by the manufacturer, and the remaining 45 hr. at 97 per cent of that speed, or 9/10ths of the power.

It is probable that 80 or 85 per cent is a lower speed-figure than might safely be used, but the experience of the National Air Transport, that exceeding this figure markedly increases its service difficulties, appears to be ample justification for its present practice.

Wide Variation in Overhaul Periods

MR. HARTSON:—Apropos of Mr. Lott's 250-hr. figure between overhauls, I was much interested in a remark by P. G. Johnson, of the Boeing company, not long ago to the effect that he had found by experiment that it was cheaper to overhaul the Wasps at 200-hr. intervals rather than to run them either for longer or shorter periods. The company tried overhauling after 300 hr. and found that the overhaul cost including replacement parts exceeded the similar cost on two overhauls each made at 150-hr. intervals, which I thought was rather significant. The company then compromised and made

[10] S.M S.A.E.—Physicist, chief, automotive powerplants section, Bureau of Standards, City of Washington.

the period 200 hr., and that is its basis. Has Mr. Lott had a similar experience?

MR. LOTT:—No. We are familiar with Mr. Johnson's method of operation and, of course, looked to him for a great deal of advice. However, we started in knowing that he overhauled his engines after 200 hr., and when we first received the engines from the factories we took them down after 200 hr. of flying. As soon as our own shop inspected them and put them together again, we felt justified in running them 250 hr., and they have been run for that period ever since. We do not feel that our overhaul cost would be reduced by overhauling them after 200 instead of 250 hr. It is just that you want to get your eyes inside of the engine and be sure that everything is all right. The replacements are not so high, but the parts do cost a great deal.

MR. HARTSON:—I should like to ask Mr. Lott, as an operator, another question that is purely theoretical. Would the operators consider at all favorably a purely commercial transport engine? It seems to me that one of the weaknesses in transport now is that we are using equipment that was originally designed primarily for military purposes. It now serves a sort of composite purpose; the same engine is used in a transport plane that is used in pursuit planes.

Suppose that an engine could be built that would operate successfully with 500-hr. inspection periods, causing some sacrifice in weight, possibly, but probably reducing fuel consumption. Would that be attractive to an operator, even at a slightly higher cost?

MR. LOTT:—I think it would be very attractive provided the fuel consumption were kept low. We can afford to stand 100 lb. more on the engine if you can take that out of the gasoline. It is the gasoline consumption that gets us into the most trouble. As far as the slightly higher cost is concerned, if we can overhaul one engine twice in 500 hr. and another engine only once in 500 hr., we can at least afford to give you the cost of the second overhaul if we get that much flying time out of it.


H. K. CUMMINGS

Pilots Not Expected to Be Mechanics

SANFORD A. MOSS[11]:—The authors made a plea for a little more knowledge on the part of the designer. I should like to ask also that the pilot of the machine have a little more knowledge than he now has. It was not so long ago that the pilot, although he knew how to jerk the sticks around, knew very little about the machine he was handling. Nowadays pilots have a higher standard, and this is a cause for congratulation.

More than once, when I have been concerned with flights with superchargers, the pilot reported that the supercharger froze. That was a standard excuse when anything went wrong with the powerplant. The actual trouble was not that the supercharger froze, but that some other part of the powerplant failed. The pilot did not have the faintest idea what the supercharger was, or any part of it. Some pilots will come in and say that the engine misses without giving details. An intelligent pilot can very often diagnose the difficulty. The pilot must be a mechanic.

MR. LOTT:—We think our pilots are more or less qualified mechanics; however, they have a job to do which depends only indirectly on taking proper care of the engine. We can employ a ground force to do that. We provide the pilots with instructions on how we want them to run the engine, and we can expect that they will do what we tell them.

So far as the supercharger is concerned, I recall that our first Wasp engine had no clutch between the supercharger or blower and the crankshaft. After one or two planes had been out, we suggested that it might be a wise thing to install a clutch there, and we were advised that it would be done on Army engines but that it was not considered necessary for commercial operation.

Puzzling Feature of Overhaul Periods

MR. GILPIN:—We have operators who use a great many of our engines and find it desirable in their activities to overhaul at periods of 200, 250 and 300 hr. One large operator is overhauling his engines at 500 hr. He told me recently that he was going to extend that to 700 or 750 hr., and he is just as certain of his accuracy as the other operators who overhaul at 200 hr. It is all a matter of reliability and cost, and, as I stated before, it is rather difficult for us to analyze and find out whether it is due to the difference in the way the equipment is operated, the climatic and ground conditions, or whether some of the operators are being misled by lack of correct information.

Possibly, under certain operating conditions on some lines, 200 hr. is the right period, while 500 hr. may be the right overhaul period at other places. Many governing factors are beyond the engine manufacturer's control, such as the fuel, oil, dirt, and the kind of service given the engine at overhauls. In general, we find that, where several engines of the same model are used by one operator, the results are consistent, one engine with another. However, another operator does not get the same service results from his engine of the same model, because of the difference in operation and maintenance, which probably accounts for operators overhauling engines at different periods of service. The condition found when engines are dismantled for overhaul should be the deciding factor as to whether the overhaul period and the handling of the engine are correct.

Engines Removed and Inspected After 100 Hr.

H. C. SAMPTER[12]:—The European lines, I have recently been told, have their engines installed so that they are very easily taken out of the planes, and are taking them out after every 100 hr. for at least an inspection in the shop, putting other engines in and keeping the planes flying.

CHAIRMAN WARNER:—That was true when I was last in Europe about a year and a half ago. I think it is also true that some of the operators in several Euro-

(*Concluded on p.* 407)

[11] Supercharger engineer, Thomson Research Laboratory, General Electric Co., Lynn, Mass.

[12] New York City.

Possibilities of the Liquid-Cooled Aircraft Engine

By Rex B. Beisel

Wichita Section Paper

ALTHOUGH reasons given by the author for the present large predominance of air-cooled engines seem to indicate that little hope can exist for the liquid-cooled engine, many engineers believe that use of the latter type will markedly increase in the next few years and that greater familiarity by airplane designers with the possibilities of the liquid-cooled engine is therefore desirable.

The function of any cooling system is described briefly and the author points out that greater air resistance is required by the direct than by the indirect, or liquid, cooling system. Shape and disposition of the air-cooled cylinders are very important to adequate cooling, whereas with liquid-cooling the designer is not limited in these respects and a very compact engine-design resulting in a small frontal area is possible. Also, the liquid-cooled engine can be completely cooled and the fuselage given a form having very low air-resistance.

Comparison is made between high-temperature liquid-cooling with ethylene-glycol and air-cooling and water-cooling in respect to fuel economy and reduction of weight and parasite resistance. Other advantages of high-temperature liquid-cooling mentioned are resistance to freezing, greater reliability, high engine-speed with geared propeller, and the suitability for housing the engine in the wing of an airplane.

Various suggested methods of disposing the radiator to decrease the air resistance are mentioned, such as its location in the leading edge of the wing, particularly in the thick wing of the monoplane; as an annular core in the nose of the airplane; or on the sides of the fuselage back of the engine. Even the possibility of dispensing with the radiator is suggested, cooling being effected through finned cylinder-jackets, thereby also eliminating plumbing.

In conclusion, the author ventures to list a number of characteristics that he visualizes, in the light of racing-engine developments, as reasonable to expect in an aircraft engine.

REX B. BEISEL

MANY believe that the liquid-cooled engine will increase in use to a marked degree in the next few years; therefore a greater familiarity on the part of airplane designers in this Country with the possibilities of the liquid-cooled engine seems desirable. Only a few designers have been fortunate enough to have had experience in the application of the liquid-cooled engine to the modern airplane. The fact that more than 90 per cent of the airplanes built in this Country are equipped with air-cooled engines is due, I believe, chiefly to the following causes:

(1) Simplicity of design of the radial air-cooled engine
(2) Light weight of this type of installation
(3) Simplicity of installation of this type of engine
(4) Application of the blower (really a supercharger) to the radial engine
(5) Lack of competition in the liquid-cooled-engine field
(6) Use up to the present of water as a cooling medium in liquid-cooled engines
(7) A definite pendulum swing from the water-cooled to the air-cooled radial engine, not directly attributable to any of the foregoing causes. Lack of competition (item 5) is the result to a large extent of this pendulum swing.

The foregoing might seem to indicate that very little hope for the liquid-cooled engine can exist, but I hope to be able to show that such is not the case. However, I do not believe and am not attempting to prove that the air-cooled engine will be supplanted by the liquid-cooled engine. The former has a very definite place and I believe will continue in use extensively, especially in airplanes of the low-priced class, in designs where very high performance is not required and in airplanes having a low endurance-range.

Before discussing the pro's and con's of liquid versus air-cooling, let us digress to consider cylinder cooling in a general way.

Indirect versus Direct Cooling

The function of any cooling system is to carry heat away from the walls of the cylinders to enable the engine to function properly. In the case of the air-cooled engine, this is accomplished through cooling fins which are directly exposed to the air-flow. In the liquid-cooled system, the heat from the explosion is transferred to a flowing liquid that is in direct contact with the cylinders and that carries it to the radiator, which

[1] Vice-president and chief engineer, Spartan Aircraft Co., Tulsa, Okla.

is exposed to the air-flow. In either case, the heat dissipated from the cylinders is, in the end, carried away by the air-flow resulting from the forward motion of the airplane. Hence a resistance in the form of skin friction, with possible added turbulence, is necessary for the transfer of this heat to the air-flow. In the case of the air-cooled cylinder, the cooling medium can carry heat only from the exposed external surfaces. With liquid-cooling, heat can be carried away from the internal parts of the cylinder by the provision of internal passages adjacent to highly heated parts of the engine. A more uniform temperature from the head to the base of the barrel is therefore possible.

In the case of the liquid-cooled system, the maximum temperature of the cylinder-walls is a function of the boiling-point of the liquid acting as the cooling medium and is not a function of the maximum allowable cylinder-wall temperature. That is, our only concern is to provide cooling to the liquid medium sufficient to prevent it from reaching the boiling-point. In contrast, our desire in the case of the air-cooled engine is to provide air-cooling to the cylinders sufficient to prevent overheating of the cylinders.

Resistance Needed for Air-Cooling

From these facts it can readily be seen that, in the case of the directly air-cooled cylinder, the design of the engine as to shape and disposition of cylinders is very important to adequate cooling. Axiomatically, it is necessary to introduce air resistance in the design of the air-cooled engine even though the desire of the airplane designer is to reduce resistance to the minimum. Not only is air resistance in the form of skin friction resulting from air flowing over cooling fins essential, but, because the air must flow past the cylinders themselves, an added resistance in the form of turbulence is introduced, as is also further resistance due to the overall fuselage shape resulting from the form of the air-cooled engine which must be adopted to assure proper cooling. This last is especially true of the radial type, in which the cylinders are placed so as to present the maximum possible frontal area, and hence resistance, per horsepower. However, the radial type offsets this disadvantage to some extent by its lighter weight as compared with the air-cooled V type.

With liquid-cooling the designer is not limited as to engine shape or cylinder location. A very compact design resulting in a small frontal area as compared with the air-cooled radial, or a short fore-and-aft dimension as compared with the air-cooled V engine, is possible, as is readily borne out in the liquid-cooled V-type engine. Furthermore, greater attention can be given in the design to the reduction of fuselage resistance; that is, it is possible to entirely enclose the engine with cowling and at the same time control the engine shape so as to permit of a fuselage form having a very low resistance-coefficient. This is especially true when using an offset geared propeller, which permits the thrust line virtually to coincide with the axis of the ideal body shape.

From the standpoint of obtaining the minimum head resistance resulting from engine design, the liquid-cooled engine is ideal. However, the additional head-resistance resulting from the radiator or other means of extracting heat from the cooling medium must be considered. Until very recently the conventional method of liquid-cooling was through water as a medium and a honeycomb or tubular radiator as the source of heat removal. The resulting increase in weight and the addition of considerable head-resistance, both from air-flow through and around the radiator and the combined unfavorable fuselage shape, have offset the advantages of the liquid-cooled engine. The wing skin-radiator, with its very low resistance, has been used, but its excessive weight, danger from freezing, and high degree of vulnerability in the case of military aircraft, have prohibited its use except in special speed planes.

Tests show that the size of a radiator becomes less as the boiling-point of the cooling liquid becomes higher. For any heat transfer, a temperature difference is necessary, and the quantity of heat carried away is directly proportional to this temperature difference. With a radiator, a temperature difference exists between the air and the cooling liquid. Assuming a maximum air-temperature of 100 deg. fahr., which is the figure normally used in computing the required radiator size, we have a temperature difference between the air and the boiling-point of water of 212—100, or 112 deg. fahr. In the case of Prestone, or ethylene-glycol, the corresponding temperature difference is 335—100, or 235 deg. fahr., which would mean a corresponding decrease in radiator size of more than 50 per cent, assuming the same specific heat of liquid and the same heat transfer from the gases.

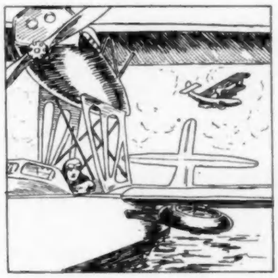
The specific heat of Prestone is, however, only about 70 per cent of that of water, which indicates that the decrease in radiator size would be less than 50 per cent. Fortunately, however, this is not the case. Tests conducted at Wright Field by the Army Air Corps, show that, with a temperature difference of only 200 deg. fahr. between the air and the Prestone, the radiator size was reduced 69 per cent, or to 31 per cent of its original area. Had the temperature difference been permitted to run as high as 235 deg. fahr., the radiator size could have been reduced approximately 74 per cent, or to 26 per cent of the original area of the water radiator. Part of this favorable discrepancy can be attributed to greater direct heat-loss to the air from the jacket-walls and piping. Tests at the Philadelphia Navy Yard were successfully conducted on an E-4 Hispaño engine at an air temperature of about 40 deg. fahr. with no radiator at all and no modifications of the jacket-wall. Another probable reason for the small radiator-size is that, with the higher-temperature Prestone, less heat transfer from the explosive mixture to the cooling medium should result, because of the lower temperature-drop between the exploded mixture and the Prestone.

Regardless of the foregoing, our interest lies in the possibilities of being able to use a radiator at most only 30 per cent as large as the conventional water-type radiator.

Admitting that the air-cooled engine is being used almost entirely in airplanes being designed in this Country, we must concede that, even though handicapped by the extra weight and resistance of radiators, a number of airplanes equipped with water-cooled en-

gines give very excellent performance. For example, we have a transport airplane having a gross weight of more than 17,000 lb., a wing area exceeding 1500 sq. ft. and engines that develop only 1250 b.hp., which has a top speed of 139 m.p.h. Considering the low wing-loading and a useful load of 35 per cent, which does not include a very complete list of fixed equipment, conveniences and furnishings amounting to more than 2000 lb., this performance deserves careful comparison with air-cooled-engine installations. We should also keep in mind that a much greater percentage of airplanes are equipped with water-cooled engines in Europe than in this Country.

These remarks are not intended to adversely criticize the air-cooled engine in any way but rather to bring to the airplane designer's attention the fact that the liquid-cooled engine has not become obsolete and that he should still give it careful consideration when designing new types of airplane. This statement is made even neglecting the possibilities of ethylene-glycol cooling. We must not lose sight of the fact that the world's speed records are held by water-cooled engines, and I have grave doubts whether the present records will ever be approached with an air-cooled-engine installation.



Possibilities of Ethylene-Glycol Cooling

Let us consider the greater possibilities of liquid-cooling when ethylene glycol is used as the cooling medium. Its advantages over water-cooling are:

(1) Better fuel-economy
(2) Reduction in weight
(3) Reduction of parasite resistance
(4) Non-freezing qualities
(5) Greater reliability
(6) Adaptability to gearing and high engine-speed.

Better Fuel Economy.—Wright Field tests show an increase in fuel economy of 20 per cent when operating at a cooling-liquid temperature of 300 deg. fahr. I believe it is conceded that the fuel consumption of the modern water-cooled engine is at least not higher than that of the air-cooled type, and, if I have been correctly informed, the fuel consumption of the air-cooled engine at full throttle is considerably higher than that of the water-cooled engine. Assuming that the high-temperature liquid-cooled engine has 20 per cent better fuel-economy than the air-cooled engine, the weight saving for a given endurance is considerable. The average airplane has a fuel-tank capacity of about 30 gal., or 180 lb., per 100 hp. A 20-per cent reduction in this capacity is a saving of 36 lb. per 100 hp. On a 600-hp. Prestone cooling-system the total weight of radiator, cooling liquid, radiator piping and supports is 134 lb., or 22 lb. per 100 hp. In the airplane tested at Wright Field, the weight of the Prestone cooling-system with 430 b.hp. is about 27 lb. per 100 hp. Assuming the higher figure of 27 lb. per 100 hp. for the cooling system, the fuel economy need be only 15 per cent better on the average airplane to offset the added weight of the cooling system. Thus it appears that the resultant over-all weight of an airplane of average endurance when using high-temperature liquid-cooling need not be greater than the present water-cooled-engine installation less the weight of the entire water-cooling system; that is, not greater than if using the dry engine alone. An even greater over-all saving will result if the airplane endurance is increased.

Reduction in Weight.—Let us now study the weight of the dry liquid-cooled engine and the air-cooled type. Using manufacturers' weights and engines of 300 hp. or more, we find that the weight of the latter is higher per brake horsepower than that of the water-cooled type. Assuming 500 b.hp., it appears that, whereas an air-cooled radial will weigh about 149 lb. per 100 b.hp., the equivalent weight of the water-cooled type of modern design will be about 131 lb. per 100 b.hp., or a weight saving of 18 lb. per 100 hp. in favor of the liquid-cooled engine.

The installation weights also favor the liquid-cooled engine. The engine-mount weights are virtually the same, as are the collector-ring and tail-pipe weights of an air-cooled engine as compared with the exhaust manifolds and tail pipes on the liquid-cooled engine. The chief saving is in cowling, due to smaller engine-size, and in heater weight. This saving, when using the N. A. C. A. type of cowl and hot-spot heater, will run to 9 lb. per 100 b.hp. on a 500-hp. installation. Use of the air-type of heater will reduce this saving in cowling and heater weight to about 5 lb. per 100 b.hp. Assuming a saving of only 7 lb. on cowling and heater and a saving of 18 lb. on the engine, the total of 25 lb. will pay for the liquid-cooled radiator weight, even neglecting the actual saving in fuel consumption previously discussed.

Comparison of Parasite Resistance

Reduction of Parasite Resistance.—This can be divided into two parts: (*a*) reduction due to smaller frontal area and better fuselage or nacelle shape as compared with the air-cooled airplane, and (*b*) reduction due to lower cooling-resistance caused by skin friction and turbulence resulting from air passing over, around or through the cooling surfaces.

The reduction in frontal area, aside from the question of visibility, gives a much greater decrease in resistance in the engine nacelle or open-cockpit fuselage than in the cabin airplane, assuming the use of the N. A. C. A. cowl on the radial type of air-cooled-engine installation. A number of planes, however, are designed with engine nacelles and, since the use of multiple engines is increasing, a reduced nacelle frontal area is extremely desirable. This is true not only from actual parasite resistance of the nacelle alone but also in connection with the greater interference resistance between the nacelle and the wing.

If I may be permitted to digress for a moment, I desire to strongly impress the fact that we have wofully overlooked the interference resistance in the design of airplanes and that a more thorough study and better understanding of this phase of aerodynamics will result in a greater improvement in airplane performance than any of us at present realizes.

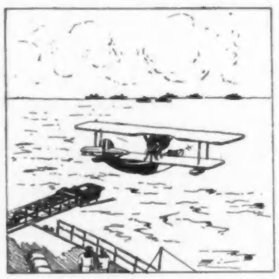
Let us now compare the frontal area of the radial air-cooled engine and the liquid-cooled V-type engine. That of the former, with the N. A. C. A. cowl, varies from 3.1 to 3.9 sq. ft. per 100 b.hp. The area of the over-all diameter of the engine has been used so as to compare the best streamline shapes, since it is conceded that the resistance of a nacelle with uncowled radial is the higher. The frontal area of the liquid-

cooled engine, assuming the minimum pear shape, is 0.85 sq. ft. per 100 b.hp. When faired into a streamlined shape, the frontal area of the nacelle, using the liquid-cooled-engine installation, is 1.4 sq. ft. per 100 b.hp. Comparing this value with the minimum value of 3.1 sq. ft. for the air-cooled radial, the decrease in frontal area is 55 per cent, and in addition the resistance coefficient is much less per square foot owing to the better streamlined shape of the liquid-cooled-engine nacelle. This analysis is also true not only of nacelles but also in the case of the open-cockpit design, but does not affect the cabin job as far as reduction in frontal area is concerned; however, the better fuselage shape and better visibility resulting from the liquid-cooled-engine installation are apparent.

Cooling resistance, that is, resistance due to air friction over the cooling surface and the resulting turbulence due to cylinders, remembering that the air-flow must necessarily take a circuitous path, is necessarily high with the air-cooled cylinder. With the liquid-cooled engine, even when using water as a medium, it is possible to obtain a low cooling-resistance by careful radiator design and disposition of cowling, that is, tunnel radiators or external streamlined radiators. By decreasing the radiator area to 30 per cent of that of the water-cooled type through the use of high-temperature liquid-cooling, the cooling resistance is reduced to a very low value. However, the final solution, as made possible by the use of liquid-cooling with the lower cooling-surface area required, is in taking advantage of the skin-friction resistance already existing in the airplane, thus obtaining adequate cooling with no increase whatever in parasite resistance.

Reduction in Cooling-Surface Area

The cooling-surface area required when using a 9-in.-core radiator or a corrugated-skin radiator is virtually the same, but if smooth-skin radiators are used the area required is lowered, since the air-flow over the surface gives a better wiping effect. Assuming, as obtained in the Wright Field tests, a required area of 16.5 sq. ft. of cooling surface per 100 b.hp. at around 160-m.p.h. top speed, and 500 b.hp. at this speed using wing skin-radiators, the wing area affected is 16.5 x 5 x ½, or 41 sq. ft. On an 8-ft. wing-chord the radiator span is just over 5 ft. This figure assumes no decrease for smooth-skin radiators and also assumes equal cooling on top and bottom surfaces and also fore and aft along the chord.



Tests conducted in England show that the foregoing is not entirely true. The upper surface, especially at high angles of attack, gives better cooling owing to increased turbulence, but the most interesting result of these tests shows that in the region of the leading edge of the wing the cooling effect due to impact pressures and better wiping is more than five times better than that of the remaining surface of the wing. These tests were conducted on a thin wing having a relatively sharp leading edge. The thick wing as used in this Country, especially on internally braced monoplanes, should be ideal as regards cooling with small cooling-surface area. Whether an area one-fifth of that normally required could be used would have to be checked by further tests, but the impact pressure at the nose of the wing is certainly conducive to small cooling-surface areas. If this installation is feasible, welded-aluminum leading edges acting as header and radiator could be used with internal return pipes, also of aluminum, which could readily be made to dissipate a large quantity of heat into the wing, if the latter is provided with a small air-circulation. What better method could be adopted to prevent ice forming on the leading edge of the wing?

Other methods of taking advantage of the small radiator-area required with high-temperature liquid-cooling will surely be developed. One suggested means is to use an annular-core radiator in the nose of the airplane. A 9-in. core of slightly more than 0.9 sq. ft. frontal area can be made to fair into the fuselage and still give an excellent shape at the nose. This scheme also permits of additional cooling through air-flow over the jacket-walls. Another idea is to place the radiator back of the engine at the sides of the fuselage, using a semi-venturi opening to improve the air-flow. A small annular opening is provided in the nose of the fuselage. Some engine designers believe that no radiator will be required, the cooling being effected through finned water-jackets. In a six-in-line engine, a fairly low head-resistance should result, as the bank can be made into a more or less streamline shape, eliminating flow between and around the cylinders. This latter avoids all plumbing problems.

Other Advantages of Prestone Cooling

Non-Freezing Qualities.—Although chemically pure ethylene-glycol has a freezing point of +12 deg. fahr., the commercial product known as Prestone does not freeze solid until a temperature of —45 deg. fahr. is reached. The use of Prestone as a safeguard against freezing is therefore ideal even in the airplane. It does not evaporate readily, as does alcohol, and in addition, because of the small radiator used, the small volume of fluid and lower specific heat, does not require radiator shutters. It is also ideal as a means of providing heat control to the inlet manifolds; the installation that is incorporated as a part of the carbureter is simple, light in weight and can be controlled to give any variation in heat. In contrast, it is much simpler and lighter than the hot-spot or air-heater as used on air-cooled engines.

Greater Reliability.—According to S. D. Heron[2], research engineer of the Air Corps at Wright Field, the high-temperature liquid-cooled engine will stand more abuse than the air-cooled type, owing primarily to the more nearly equal heat-distribution resulting from the circulation of the liquid cooling-medium. It is also pointed out that a single thermometer in the outlet from the engine at once gives warning of overheating of any part of the engine. Contrast this with the usual warning of overheating in the air-cooled engine.

Two-Fold Advantage of Geared Engine

Adaptability to Gearing and High Engine-Speed.—Modern engine-design practice indicates that the maximum power that can be developed in a single air-cooled cylinder under sea-level conditions, at the same time obtaining adequate cylinder-cooling, is about 60 b.hp.

[2] See S.A.E. JOURNAL, October, 1929, p. 343.

This means that it is impracticable to obtain increased power with the air-cooled cylinder by means of high engine-speed and the application of a supercharger. Besides the fact that high engine-speed with an air-cooled cylinder involves cooling difficulties, the geared propeller, with lower air-velocities over the cylinders, introduces an additional cooling problem.

The power that can be developed in a single cylinder of the liquid-cooled engine is limited only by the supply of fuel mixture and the design of the moving parts. Adequate cooling can always be provided. Experience has shown that the heat dissipation to the cooling liquid per brake horsepower developed becomes less and less as the revolutions per minute increase. Apparently this is due to the decrease in the time interval of heat-flow from the exploded mixture through the cylinder-walls into the cooling liquid; that is, heat-flow is impossible without a temperature gradient and a time interval. If the piston moved very slowly, almost all of the "slug" of heat in the cylinder would flow through the walls into the coolant. This would include the heat at the very center of the "slug." Theoretically, if the burning of the mixture were instantaneous, with instant opening of the exhaust valves, there would be no time interval permitting heat-flow through the cylinder-walls, the heat generated passing out through the exhaust. High engine-speed approaches this condition and reduces the heat dissipation to the coolant and increases it into the exhaust. Hence the advantage of high engine-speed is two-fold: more power can be developed per cylinder and less cooling surface is required per horsepower. The result is a very marked saving in weight both in engine and cooling system, and is enough to more than make up for the added weight of a supercharger and gearing, with all the advantages of the geared propeller and small frontal area.

Characteristics of Future Engine Visualized

Naturally, development of high-temperature liquid-cooling has met with a number of difficulties but to date none of these has been at all insurmountable. It should be borne in mind in this connection that all experiments with this method have been made on engines designed originally for low-temperature liquid-cooling. Fortunately, the design of the air-cooled cylinder, with its high operating-temperatures, has progressed sufficiently so that a great deal has been learned about the effect of high temperatures on engine parts and their operation. This information, together with what has already been learned in experimental work with high-temperature liquid-cooling, should enable the engine designer, cooperating with the plane designer, to obtain a powerplant-airplane combination that will be a decided forward step in aeronautic development.

In the light of racing-engine development, it seems reasonable to visualize an aircraft engine having the following characteristics:

(1) Frontal area, when cowled into the fuselage or nacelle, not greater than that of present water-cooled engines of 600 b.hp. without radiator; that is, not greater than 8 or 9 sq. ft.
(2) Speed of 3000 to 3500 r.p.m.
(3) Power output of 1000 to 1200 b.hp.
(4) Supercharged to obtain maximum horsepower at small and great altitude
(5) Weight less than 1 lb. per b.hp.
(6) Geared drive
(7) High-temperature liquid-cooled, with no added head resistance due to cooling.

For those of us who believe that the airplane of the future will be of the so-called flying-wing type, such an engine would be ideal. It would house nicely into the wing with only the propeller-shaft projecting. Problems of resistance, interference, spoilage of wing section and engine overheating would be effectively controlled or overcome. Low weight and maximum performance would approach the ideal. Certainly, if such an airplane is to be reckoned with as a future possibility, it will not be equipped with directly air-cooled engines.

The Operator's Airplane and Engine Requirements

(Concluded from p. 402)

pean countries show a tendency to trust their engines with passenger-carrying planes to an extent that would be rather alarming to most of the travelers and operators in this Country. Whether that is justified or not I am not at all sure; if it be justified, I cannot say whether it has anything to do with the time between overhauls. I have several times flown out of well-known airports, going over the field without circling it at all, and straight over the center of a very large city.

ERIC GEERTZ[13]:—We have had a whole session on engines, and nobody has as yet mentioned the propeller. It seems to me that has an important bearing in translating engine rating into transport performance. Do existing propeller characteristics cause Mr. Lott's organization any concern, under the varying conditions of flight that he encounters in transport work?

MR. LOTT:—We have very little propeller trouble. Our standard Liberty propeller is not at all the Army standard, yet we are very much satisfied with it. We set the propellers so that they run full throttle in the air at 1750 r.p.m., and we cruise them at 1480 r.p.m. The radial engines are set to run at 1950 r.p.m. at full throttle, and we cruise them at about 1625 r.p.m. Every once in a while somebody brings out a new propeller and we try it. If it seems to give us better performance than the previous one, we are glad to get some more of them. We have settled on two propellers that seem to do the work very well, and, until a better one comes out, we are well satisfied.

[13] Jun. S.A.E.—Automotive engineer, Link-Belt Co., Indianapolis.

Engines Having the Cylinders Parallel to the Shaft

Indiana Section Paper

By E. S. Hall[1]

SOME early gasoline engines had their cylinders arranged around a shaft, with axes parallel to the shaft. This arrangement has appealed to many inventors, and the author presents a number of such engine designs gleaned from the records of the patent office, all but one or two of them being American.

This part of the paper is introductory to the description of one engine of the same class in which the reciprocating motion is transformed into rotary motion through slippers bearing on a swash-plate, an essential feature being the provision for oil-wedge lubrication such as has been very successful in turbine and marine thrust bearings.

Automobile and other engines, compressors and pumps embodying this mechanism have been built, tested and operated in service during the last decade. Some of them are briefly described, and dynamic balance and other problems connected with them are discussed.

AMONG reciprocating-piston machines is a class characterized by the arrangement of the cylinders parallel to and equidistant from the main shaft. Some of these machines have been called barrel engines; in others, the resemblance to a barrel is rather slight. The entire group has been more correctly designated as round engines, because their common and distinguishing characteristic is a circular or cylindrical plan or arrangement of the elements.

Surprisingly little technical literature exists on round engines, and the very terms used in discussing them are not generally understood, but hundreds of patents have been issued on such engines. Among them all, aside from the individual-crank type shown in Fig. 1 and a few other complicated and impractical machines, are only four kinematically different mechanisms. The patentees adhere to these mechanisms in approximately the following proportions:

	Per Cent
Cylindrical cam, driven by roller "followers"	28
Conic crank	22
Wabble-plate	40
Swash-plate	2
Miscellaneous	8

Many cylindrical-cam engines have been invented and built. Among their alluring possibilities is that of four strokes per revolution with an extra long exhaust stroke for more complete scavenging. Fig. 2 shows a cam-ridge engine having four strokes per revolution. In Fig. 3 the other extreme is approached, the shaft having three revolutions per stroke. Fig. 4 represents a cam-groove engine with swinging links to take the side-thrust reaction of the cam on the reciprocating members. Success with cylindrical-cam engines seems to hinge upon the problem of how to make the rollers run quietly and for a suitably long period of operation.

Conic-Crank Type Has One Advantage

Conic-crank engines are characterized by the fact that the crankpin extends at an angle on but one side of the main axis of the machine, the axis of the crankpin describing a single-ended conical surface. Another and favorable characteristic is that the axial thrust on the plate is not taken on the crankpin bearing, but is supported by the frame of the machine, either on a spherical pivot or on conical rolling surfaces.

Fig. 5 is a section of the West steam-engine, patented in 1875. This machine is mentioned in Heck's Mechanism, and its failure is there attributed to the eccentric plate valve used, rather than to the conic-crank mechanism.

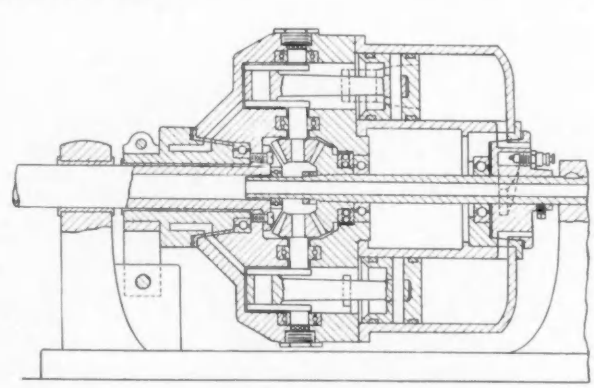


FIG. 1—INDIVIDUAL-CRANK ENGINE, PATENTED BY E. W. HELM IN 1913

[1] M.S.A.E.—Automotive Engineer, Michell-Crankless Engines Corp., New York City.

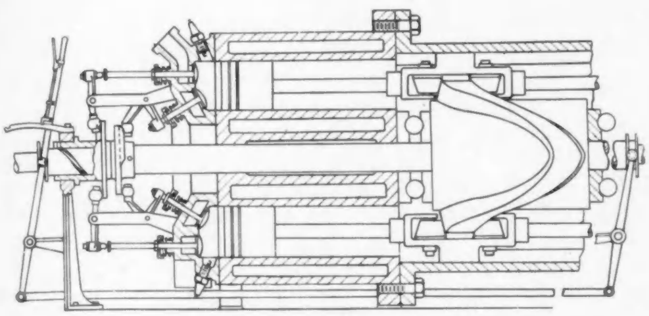


Fig. 2—P. W. Murphy Patent, 1921

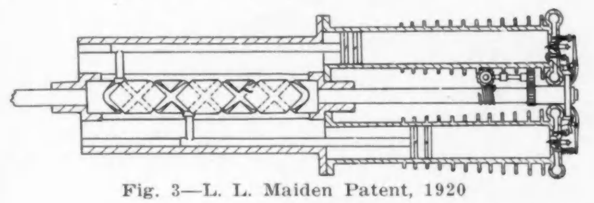


Fig. 3—L. L. Maiden Patent, 1920

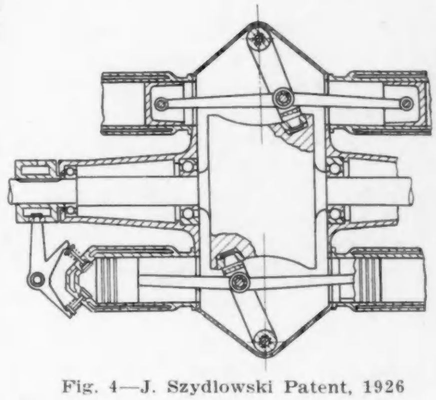


Fig. 4—J. Szydlowski Patent, 1926

THREE CAM-TYPE ROUND ENGINES

A conic-crank internal-combustion engine is seen in Fig. 6. The arc sliders are provided to prevent the crank plate from rotating. The connecting-rods have to be universally jointed at both ends.

In the mechanism shown in Fig. 7, rotation of the crank-plate is prevented by its Hooke-joint mounting. Another attempt to use a rotary valve is depicted in this drawing.

Fig. 8 shows the crank-plate integral with the conic-crank bearing, instead of with the crankpin. Bevel gears prevent rotation of the crank plate, and hardened steel conical rolling surfaces take the axial thrust.

The conic-crank mechanism is in some respects particularly suitable for air-cooled aircraft engines. Some of the problems involved may tax the ingenuity of the designer, but the mechanism has interesting possibilities.

Wabble-plate mechanisms are distinguished from the preceding group by the fact that the crankpin axis extends on both sides of the axis of the main shaft, describing a double-ended conical surface. Moreover, the wabble-plate bearing on the angular crank supports the longitudinal thrusts as well as the turning effort due to all the pistons.

The distinction between the conic crank and the wabble-plate is clearly illustrated by a comparison of Fig. 8 with one end of Fig. 9. The latter shows also a rotary valve in a central location between opposed pistons.

Fig. 10 is from an early patent of one of the best-known wabble-plate engines. A ball and socket joint with exterior faces slidable on flat seats in the double-ended piston, the amount of sliding being controlled by the studs, was designed to accommodate the bent figure-eight motion of the wabbler arm. The wabble-plate is prevented from rotating by gear teeth which mesh with two stationary bevel gears. Fig. 11 is from a later patent of the same line of machines. Note the plate valves, which have both an eccentric and rotary motion, their masses being cleverly utilized to assist in the dynamic balance of the engine. The shaft is hollow, to permit shooting a machine gun through it.

Fig. 12 represents a two-stroke-cycle wabble-plate engine in which the pistons at the rear end are used to precompress the charge. A wabble-plate engine without an angular crank is seen in Fig. 13. Inside the rim of the flywheel, at opposite sides, are mounted two rollers which maintain the plate at an angle. Bevel gears prevent the plate from turning, as in Fig. 10.

Fig. 14, taken from a hydraulic-gear mechanism, shows a relatively simple type of joint for connecting the reciprocating members to the wabble-plate. It comprises essentially a Hooke joint in which a radially projecting pin on the wabble-plate passes transversely through a larger pin that is journalled cross-wise in

FOUR CONIC-CRANK ROUND ENGINES

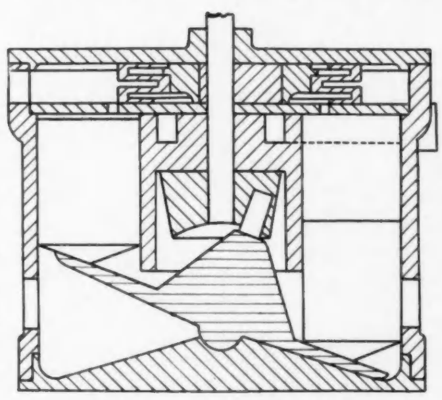


Fig. 5—D. K. West's Steam-Engine, Patented in 1875

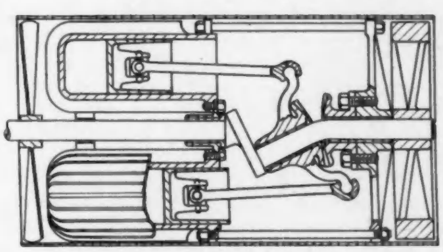


Fig. 8—J. D. Maxwell Patent, 1905

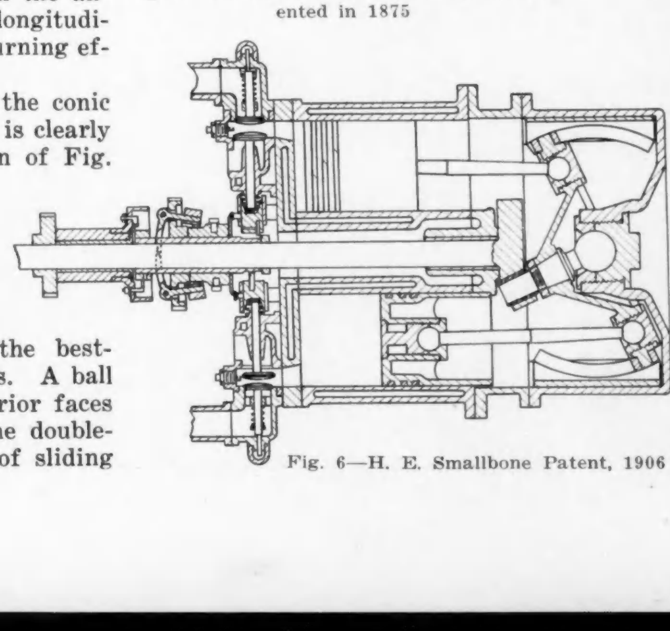


Fig. 6—H. E. Smallbone Patent, 1906

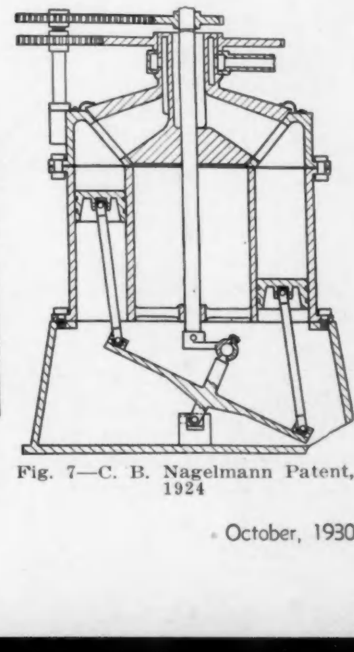


Fig. 7—C. B. Nagelmann Patent, 1924

TABLE 1—TEST DATA FROM 100-HP. MICHELL COAL-GAS ENGINE

Brake Horsepower	112.5	100	62.5	31.2
Indicated Horsepower	125.0	112.2	77.2	42.5
Mechanical Efficiency, per cent	90.0	89.0	81.0	73.5
Brake Thermal Efficiency, per cent		26.8		

the reciprocating member, both pins being allowed a certain amount of axial freedom.

A rotary engine of the wabble-plate type is represented by Fig. 15. In distinguishing the wabble-plate engines from the swash-plate group following, it is important to note that the wabble-plate does not rotate with the shaft; it merely wabbles and is usually held positively against rotation, although in a few instances it is allowed to creep slowly at will. In this rotary engine, the wabble-plate rotates with the cylinders, while the shaft is stationary. The wabble-plate is normally a non-rotating member.

Swash-Plate Rotates with Shaft

The swash-plate is a rotating member. It may be forged integral with the main shaft, bolted to it, or fastened in any other desired way, but the characteristic distinguishing this group from the preceding is that the swash-plate rotates with the main shaft.

A few mechanisms have a swash-plate and also a non-rotating plate or cage having the motion of the wabble-plate, like the example in Fig. 16. A wabble-plate that is mounted on thrust bearings between rotating thrust faces, instead of on a journal bearing, also approaches the same hybrid type.

Among patented round engines, swash-plate mechanisms are by far the smallest group. The most prominent mechanism, not only in this group but among all round engines, is the oil-wedge mechanism invented and developed by A. G. M. Michell, of Melbourne, Australia, who is internationally known as an authority on lubrication and as the contemporaneous inventor with Albert Kingsbury of the well-known, pivoted-segment thrust bearings, widely used for turbine and marine propeller thrusts. These bearings have a thrust collar integral with the shaft, running between two groups of pivoted segmental pads. Two views of such a pad are seen in Fig. 17. Each pad is supported on a hardened pivot located usually a little behind the center of pressure on the pad, as seen in the view at the left, so that the pad tends to tilt, and rides on a self-generated wedge of oil. Long experience with these bearings has conclusively proved them to be extremely efficient and durable, even under very severe service.

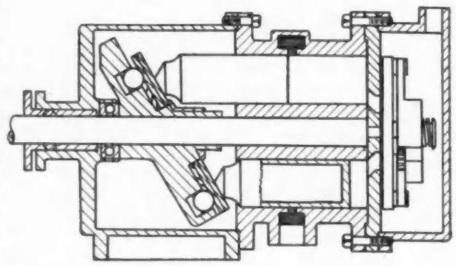


FIG. 16—C. L. SPARKS SWASH-PLATE ROUND STEAM-ENGINE, PATENTED IN 1897

The Michell engine mechanism is essentially such a thrust bearing, with the collar set at an angle from normal and the slipper pads in pairs seated in spherical cups carried by the reciprocating units. One pad of each pair is located on each side of the collar, which is now called a slant. Fig. 18 shows a sectional view of a 300-hp. coal-gas engine built in this manner. The

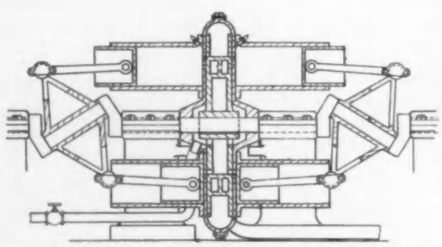


Fig. 9—C. Beckmann Patent, 1910

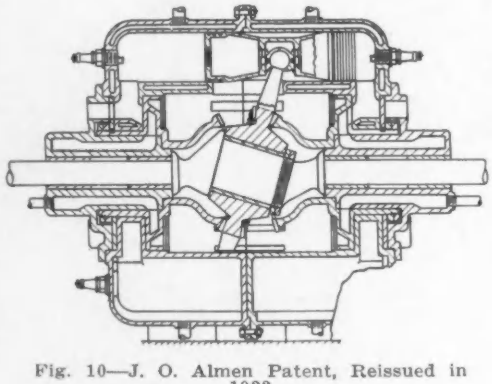


Fig. 10—J. O. Almen Patent, Reissued in 1922

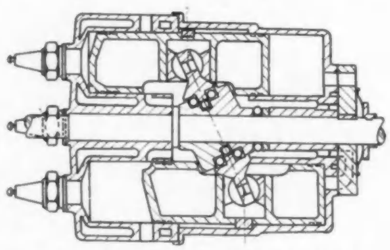


Fig. 12—A. Lind Patent, 1926

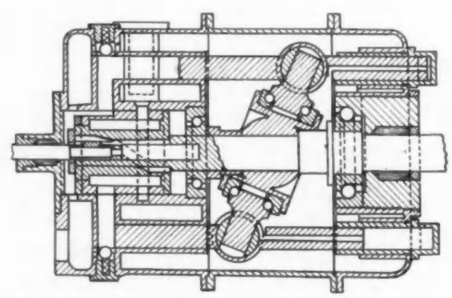


Fig. 14—Gerardine British Patent of Hydraulic Machine

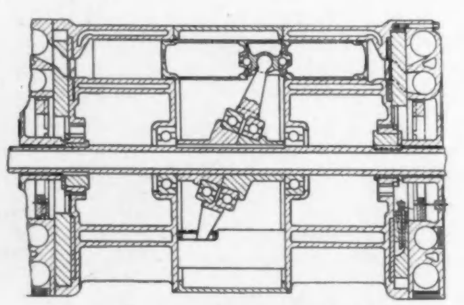


Fig. 11—J. O. Almen Patent, 1922

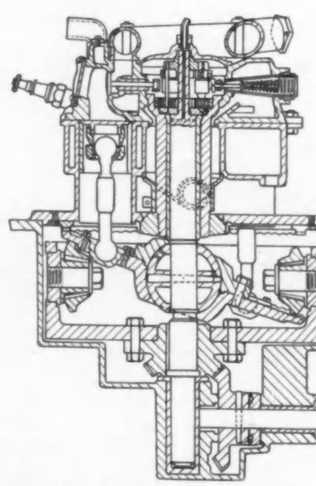


Fig. 13—J. C. Soemer Patent, 1919

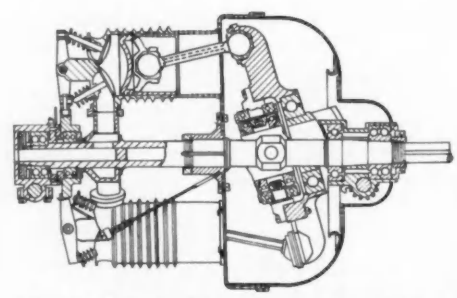


Fig. 15—W. G. Macomber Rotary Engine, Patented in 1912

SEVEN WABBLE-PLATE ROUND ENGINES

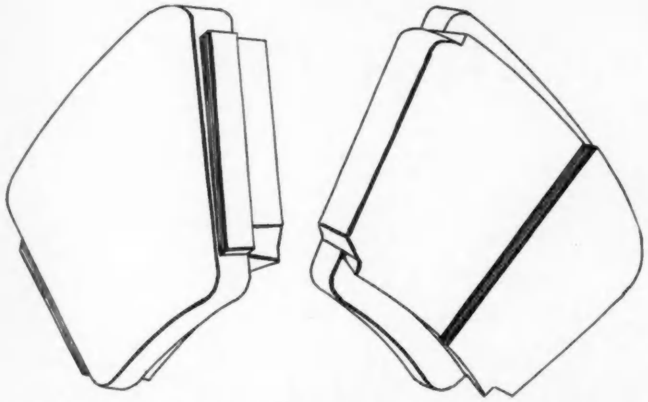


FIG. 17—THRUST PAD OF MICHELL MARINE THRUST BEARING
The View at the Left Shows the Pivot Groove, Which Is Offset from the Center. The View at the Right Shows the White-Metal Face, Which Is Rounded at the Leading Edge

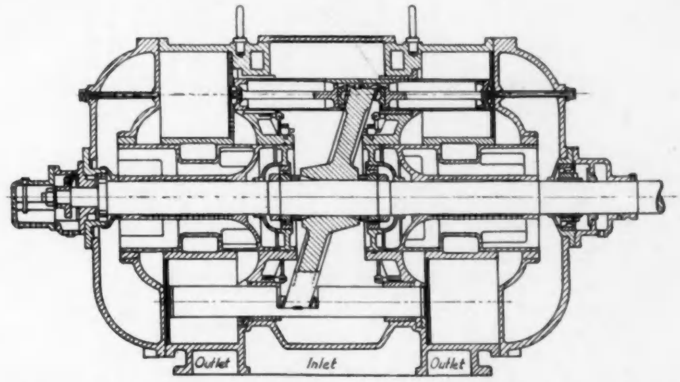


FIG. 19—CRANKLESS GAS BOOSTER THAT IS COUPLED TO THE ENGINE SHOWN IN FIG. 18

slant is, geometrically, an oblique slice from a cylinder, having parallel plane faces. There is nothing complicated about the shape and its manufacture is easy. The two spherically-backed slippers have plane faces in proximity with the two plane working surfaces of the slant, and are seated in cups co-axial with the pistons. This eight-cylinder engine has valves in the heads, operated by four horizontal camshafts.

Fig. 19 is a section of a crankless gas booster having a capacity of 500,000 cu. ft. per hr. at 750 r.p.m. and about one-half atmosphere pressure difference. The double-acting pistons are carried by tubular crossheads in which the slippers are seated, the side thrust on the reciprocating members being taken by the crosshead-guide bushings. Combined engine and booster units of this type have been in successful and continuous service for a number of years, this field being one of the first to be successfully entered by Crankless Engines, Ltd., of Australia.

Data from a test on a 100-hp. coal-gas engine used in this gas-booster service are given in Table 1. The normal speed of the engine is 750 r.p.m. Tests of other units, of various sizes and types, have shown that the mechanical efficiency of the Michell-engine mechanism compares favorably with that of a comparable crankshaft mechanism.

Oil Wedge Reduces Slipper Friction

Until the construction is thoroughly understood, the high mechanical efficiency of the Michell engine is surprising, in view of the high bearing speeds at which the slippers operate on the slant. Fig. 20 is a sectional view of an elementary form of reciprocating unit with the slippers in place. The slipper is provided with a tail to keep it correctly aligned, so that it will run with the extended side ahead, as shown in Fig. 21. The slipper is eccentrically supported relative to the face, as in the thrust bearings described, so that the pad tends to tilt, riding always on a self-generated wedge of oil that prevents metallic contact between the slipper and the slant. The oil wedge is a secret of the practical success and the high efficiency of the Michell engine. Wear is virtually non-existent so long as the oil is kept reasonably clean. The pulsating character of the load in the engine mechanism is even more favorable for lubrication of this sort than are the steady loads of the thrust bearing.

Another secret of the efficiency of the Michell mechanism is illustrated in Fig. 22, a polar diagram of the side thrust on the reciprocating unit of a typical engine. In the crank engine, the side thrust on the piston is first toward one

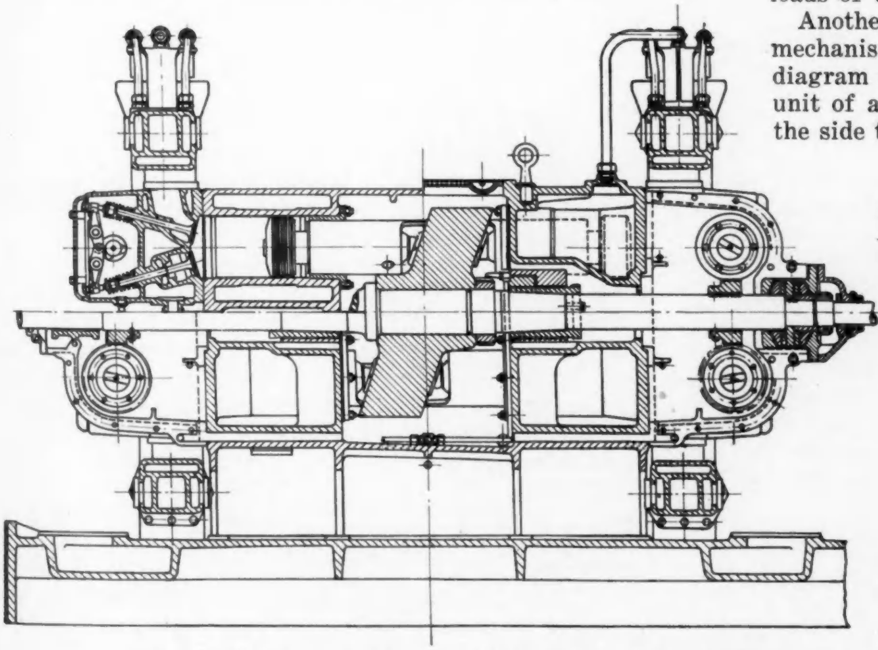


FIG. 18—SECTION OF MICHELL 300-HP. COAL-GAS ENGINE

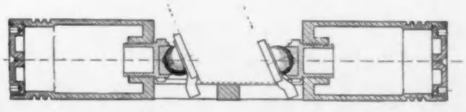


FIG. 20—ELEMENTARY FORM OF RECIPROCATING UNIT FOR MICHELL CRANKLESS MACHINE

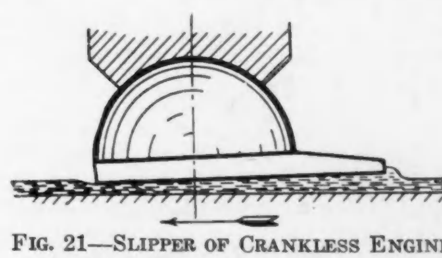


FIG. 21—SLIPPER OF CRANKLESS ENGINE, SHOWING WEDGE FORM OF OIL FILM

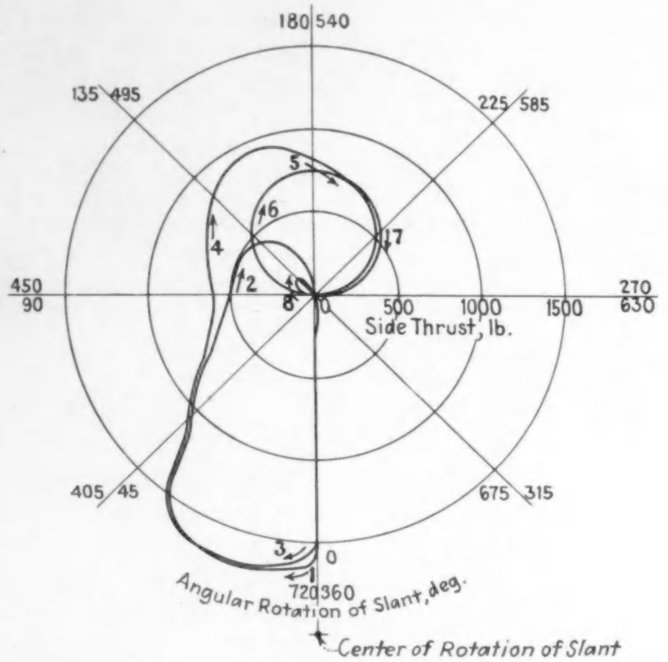


FIG. 22—POLAR DIAGRAM OF SIDE THRUST ON A TYPICAL RECIPROCATING UNIT

The Numbered Arrows Indicate the Course of the Curve

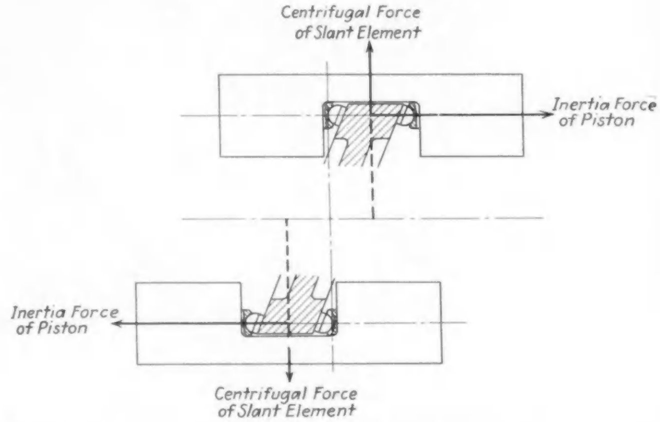


FIG. 23—DIAGRAM ILLUSTRATING BALANCE OF CENTRIFUGAL AND INERTIA FORCES

side and then toward the other, a condition resulting in piston slap whenever the clearance becomes slightly too great. In the Michell engine, the side thrust is essentially rotating in character, so that piston slap is avoided. It is also possible, as illustrated in Fig. 19, to carry the side thrust in bushings instead of directly on the cylinder walls. The rotating character of the side thrust, combined with the reciprocating motion of the piston member, is ideal for the production of true wedge-film lubrication of the sort that exists in any good journal bearing.

The Michell engine possesses inherent smoothness without the use of dampers or counterweights. The shaft is relatively short and stiff, so that torsional resonance is avoided, and the piston motion is purely harmonic, not distorted as in the crank engine. The balance can be mathematically perfect, since it is possible and convenient to exactly balance the inertia effects of all the pistons with the rotating effect of the slant, provided there are three or more reciprocating members, uniformly spaced about the shaft.

It can be shown mathematically that the summation of all piston-inertia moments about an axis perpendicular to the shaft is of constant magnitude. This total moment revolves with the slant. The slant itself has a tendency to swing to a position normal to the shaft, and this tendency produces another moment in the same plane and exactly opposed to the piston-inertia moment, as indicated in Fig. 23. By correct design, these two moments can be made equal, thus counteracting any tendency to vibrate. The equation for balance is

$$m_s = 2\,n\,m_1 \frac{C\,r^2}{A^2 + a^2} \qquad (1)$$

in which

A is the outer radius of the slant
a is the radius of the symmetrical hub of the slant
C is a coefficient somewhat greater than 1, such that $C\,r = r_m$, r_m being the radius of the center of mass of the reciprocating unit
m_s is the mass of the slant
m_1 is the mass of one reciprocating unit
n is the number of reciprocating units
r is the cylinder-circle radius

The firing order for an eight-cylinder four-cycle Michell engine may be: 1, 2, 1a, 4, 3a, 4a, 3, 2a, the power impulses being uniformly spaced at intervals of 90 deg. of shaft rotation. When an odd number of cylinders is used on each end, the power impulses are not uniformly distributed. For example, in the ten-cylinder engine, the firing order is: 1, 3, 5, 2, 4, at each end, No. 4a following 36 deg. after No. 1 and No. 3 following 108 deg. after No. 4a. If a concentric valve mechanism or the successful rotary valve is to be used, an odd number of cylinders is necessary at each end. It is possible to serve 10, 14, or 18 cylinders from two rotors, one at each end.

Michell Engine Tested in Automobiles

An eight-cylinder Michell automobile engine of 3 5/16-in. bore and 3½-in. stroke, giving about 241 cu. in. displacement, follows the cylinder arrangement shown in Fig. 18. It has two vertical camshafts, located midway of the length of the engine and driven from the main shaft by bevel and spur gears. Valves are in the heads, operated by push-rods and rockers. The slant is of forged steel, 10 in. in diameter and 2 in. thick, weighing 40 lb. The total weight of each double-ended piston is 7.2 lb., the trunk-type pistons being of aluminum and the bridge of forged steel. Two such engines were built seven years ago. One of them has been cut away for exhibition purposes, and the other is still in service.

The design has been criticized because of the poor accessibility of the rear and lower cylinders and their valve mechanism. Recent work has shown that it is possible to provide satisfactory accessibility at both ends.

In the meantime, a single-ended engine was built to avoid this criticism. It has five cylinders, all forward of the slant. Each piston, of light alloy, is bolted to a bridge which spans the rim of the slant and has a slipper bearing on each of the two slant surfaces. The bridge is guided in an enlarged bore concentric with the cylinder. All of the five cylinders and the slant case are in a single casting.

(*Concluded on p. 476*)

Combustion-Chamber Progress Correlated

By Alex Taub[1]

Semi-Annual Meeting Paper

PREVIOUS papers on Combustion-Chamber Design by three leading authorities on the subject showed enough points of real or apparent disagreement to leave the designing engineer in doubt on many of the details of design which they discussed. The author of this paper was asked to make a study of the works of these three authorities to discover points of agreement and clarify the subject for the benefit of engineers in general.

Requests were made that each of the three authors in question furnish a list of his writings to be considered in this connection. Such lists were received from Mr. Ricardo and Mr. Janeway, but not from Mr. Whatmough in time for use in preparing the original paper. After the paper was delivered, a letter was received from Mr. Whatmough, and revisions in the paper have been made on the basis of that letter.

Credit is given to Mr. Ricardo for initiating the study of combustion-chambers and inspiring other workers. He advocated turbulence in his earlier work and later promoted control of the rate of burning of that portion of the charge which is ignited first.

Whatmough is essentially a physical chemist; and his work is difficult for engineers to follow, partly because he abandons theories of thermodynamics.

Discovery of the principle of preventing detonation by cooling that portion of the charge which is last to burn is credited to Mr. Janeway, although conditions giving the same effect were found in Mr. Ricardo's designs. Mr. Ricardo has since subscribed to this principle. Mr. Whatmough has introduced the narrow clearance space in some designs, but has not definitely subscribed to it as a principle.

The rough performance obtained from the turbulent combustion-chambers called for improvement. Mr. Ricardo attacks this by controlling turbulence, Mr. Whatmough by controlling the temperature of the unburned mixture, and Mr. Janeway by control of the area of the flame front. Acceleration of the rate of pressure rise, as proposed by Mr. Janeway, is accepted by the author as a yardstick of roughness.

The paper concludes with an enumeration of five principles that the author finds to be common in the work of the three investigators, including cooling the last gas to burn by means of a shallow clearance space; locating the spark-plug near the exhaust valve; non-compact combustion-chambers; volume control for smoothness; and controlling the acceleration of the rise in pressure, to prevent roughness.

Discussion presented at the meeting by Mr. Berry urged a study of combustion-chamber design as it influences steady idling and high-speed missing. Requirements as to these, which are considered largely as problems of carburetion, cannot be met unless conditions are right in the combustion-chamber. Mr. Janeway and Mr. Taub consider this to be largely a question of having the good part of the mixture at the spark-plug, and Mr. Taub showed how the trouble had been remedied in one combustion-chamber of peculiar form by modifications. Other discussers told of instances in which these difficulties had been caused by overlapping of the valve openings.

Written discussion has been received from all three of the writers whose works were reviewed. Mr. Ricardo expresses agreement with Mr. Janeway in nearly all his conclusions, and states that the conclusions have been reached by similar reasoning. He explains his early insistence on turbulence by the fact that engines of the slower speeds that formerly were common did not produce so much turbulence as present engines of higher speed. The only difference between himself and Mr. Janeway which he mentions as significant is that he considers the use of a variable-compression engine or of graded fuel mixtures to be a much better method of testing for detonation value than that of border-line ignition advance.

Mr. Whatmough, in his contribution, says that the difficulty in understanding his work applies equally to that of all modern heat theorists and that thermodynamics is virtually superseded in the newer sciences by the quantum heat theory. He refers to a summary which appeared at the end of a series of his articles in which the conclusions were couched in ordinary engineering terms.

The control of heat throughout the cycle is aimed at by Mr. Whatmough, who criticizes the paper as being confined to only a small portion of the cycle and infers that the means discussed are much more limited than those which he proposes. The cooling compression-space, for instance, he regards as one of several means of controlling the temperature of the compressed charge.

Mr. Janeway maintains that his method of securing variation in the rate of pressure rise by calculations based upon the fundamentals of reaction rate is superior to any cut-and-try method.

THE OBJECT of this review is to clarify for those interested the technical state of the art as it exists to date for combustion-chambers. This, we believe, can be accomplished by an anlysis and comparison of the works of H. R. Ricardo, Robert N. Janeway and W. A. Whatmough.

Progress on combustion-chambers was initiated by Ricardo before 1919. Since that time he has contributed a great deal to the subject, as also have others. In fact, these other contributors may be credited with

[1] M.S.A.E.—Research engineer, Chevrolet Motor Co., Detroit.

having inspired Ricardo to finish his work, even as Ricardo was undoubtedly their inspiration in the beginning.

PART 1—RICARDO'S WORK ANALYZED

Reviewing the published work of Ricardo is a technical treat; he has done so much; he has built so much. No one man or organization has gone to the extreme that Ricardo has to develop and prove or disprove his theories. We are, however, interested only in Ricardo's work on combustion-chambers, which is but a portion of his efforts.

In August, 1919, Ricardo published[2] a paper covering a series of tests on a small Continental engine. His tests satisfied him that this engine possessed a peculiar lack of range, inasmuch as the valve size and valve-opening diagram were such as to promise a much better high-speed performance than was realized.

In an effort to improve conditions, two major changes were made:

(1) An aluminum slipper-type piston replaced the original cast-iron piston.

(2) A new type of combustion-chamber was provided, incorporating greater turbulence, greater depth and at the same time a greater compression ratio of 4.84:1, relying on turbulence to check any tendency to detonation.

The original head was of the tapered-roof type with a compression ratio of 4.45:1. The results obtained are charted in Fig. 1, which shows in full lines the horsepower with both the old and the new head, and the friction horsepower with both the original and the new piston. The dotted line indicates the horsepower for the combination. This certainly showed a great improvement, and it is typical of the type of work that Ricardo was doing. In the article[2] to which reference was made, Ricardo analyzed his result with this new head and credited turbulence with the success, because of its effect on speeding up flame and aiding detonation by improving the cooling of flame by the more rapid motion of the chamber contents against the wall.

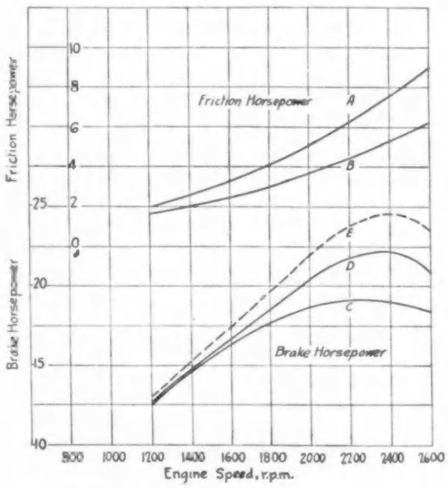


FIG. 1—INCREASE IN HORSEPOWER FROM IMPROVING THE ENGINE

Curve *A* Shows the Friction Horsepower with the Original Cast-Iron Piston and Curve *B* the Friction Horsepower with the Slipper-Type Aluminum Piston. Curve *C* Shows the Brake Horsepower of the Original Engine, Having 4.45:1 Compression. Curve *D* Is the Horsepower with the Turbulence-Type Head Giving 4.85:1 Compression. Curve *E* Indicates the Brake Horsepower with the Turbulent-Type Head and Slipper-Type Aluminum Piston

Ricardo Was the Pioneer

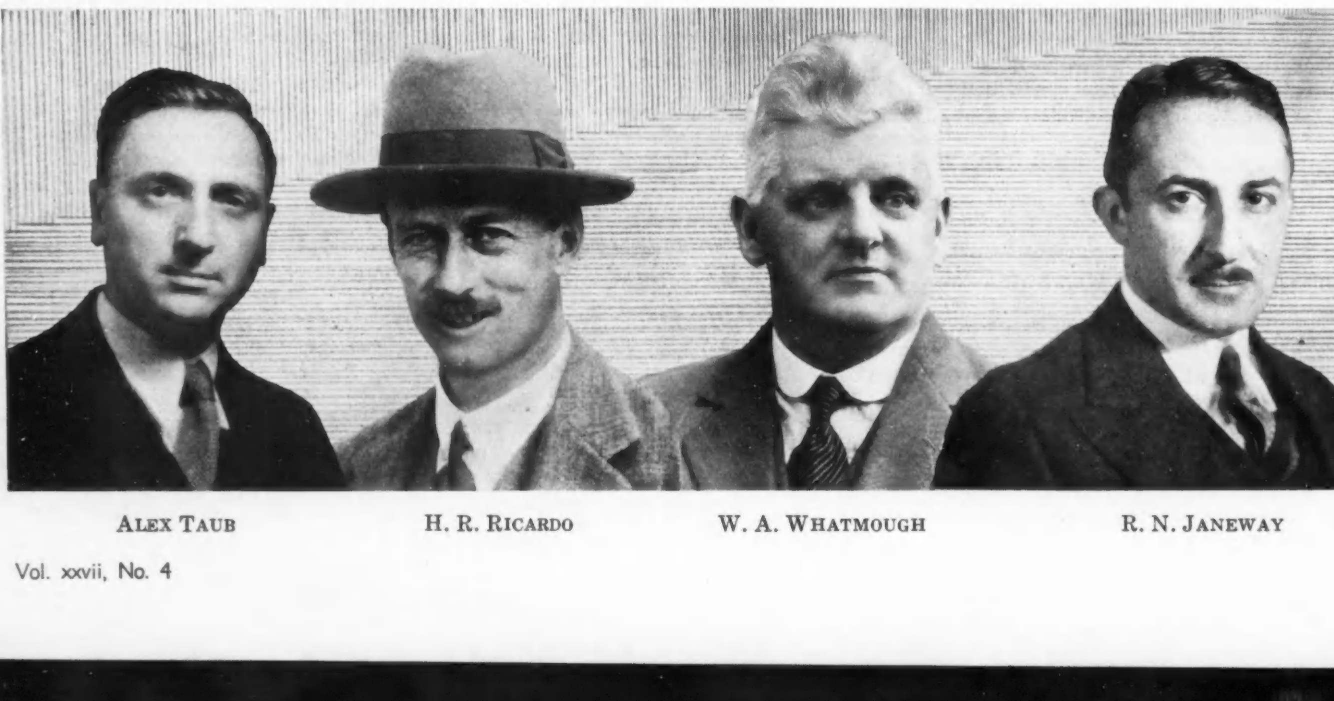
We believe that Ricardo is responsible for our becoming combustion-chamber conscious. This does not mean, however, that he has always been right. He freely admits that his combustion-chamber beliefs have constantly changed with his own progress.

Since contributions on this subject have been made by Janeway in this Country and Whatmough in England, the situation has become considerably confused. Contrary theories are propounded, the proponent of each claiming the same final result. As honest men do not disagree on facts, it is obvious that the theories are interlocked if each arrives at the same final result, in this case a smooth antiknocking cylinder-head; and one set of coordinated facts must exist which are used, consciously or unconsciously, by Ricardo, Janeway and Whatmough. I shall endeavor to show that such common characteristics do exist, and to determine their nature.

Ricardo visited this Country in 1922 and read a very comprehensive paper on Research Work on the Internal-Combustion Engine[3]. Detonation was the lone primer for his combustion-chamber investigations at that time. Ricardo explained the phenomenon of detonation as the creation of an explosive wave, or an almost instantaneous pressure rise caused by the super-

[2] See *The Automobile Engineer*, September, 1919, p. 236.

[3] See THE JOURNAL, May, 1929, p. 305; TRANSACTIONS, Vol. 17, 1922, Part 1, p. 1; *The Automobile Engineer*, September, 1922, p. 265; October, 1922, p. 299, and November, 1922, p. 329.



ALEX TAUB H. R. RICARDO W. A. WHATMOUGH R. N. JANEWAY

compression of the unburned portion of the mixture by the very rapid pressure-rise of the burning portion to a point where the temperature rise of the unburned portion is faster than the heat can be transferred. At this point the unburned portion ignites at one time, increasing the pressure rise of the whole burning charge, with a possible springing of the walls of the chamber.

Under this process Ricardo states[4]:

> Therefore, it would appear fairly certain that detonation depends primarily upon the rate of burning of that portion of the charge first ignited, and it remains to discover what actually controls this rate.

This phase of Ricardo's work is the most interesting to those engaged in the work in this Country. This explanation of the phenomenon of detonation has shed necessary light and served to inspire me and many others, including Janeway, to carry on with our own investigations.

Ricardo's explanation as to the superheating of the unburned portion by compression of the burned portion is the most important factor in all combustion-chamber theories to date. Here Ricardo gracefully pointed to a great truth and then transgressed, for he ignored the obvious. He assumed that detonation depends upon the rapidity of the pressure rise of the portion of the gas first ignited and its effect in building up the temperature of the unburned portion, and therefore the initial pressure-rise must be controlled. Ricardo apparently overlooked the possibility of controlling the temperature of the last portion to burn by modification of the surface-to-volume ratio. This is in spite of the fact that his original combustion-chamber incorporated a high surface-volume ratio for the last portion to burn.

Soft-Pedalling on Turbulence

Ricardo made his first published disavowal of turbulence in this same paper, in a further explanation of how to control the pressure rise of the first gas to burn. He states[4]:

> From more recent investigations, my belief in this has been considerably shaken. I now feel bound to confess that I can find no real evidence that turbulence, while invaluable for other reasons, influences detonation one way or the other.

The probable reason for the dropping of turbulence as the major factor in detonation control is that it was necessary to Ricardo in the light of his new theory, which made necessary the control of the rate of burning or pressure rise of the first gas to burn. More turbulence meant increased rate of pressure rise, and he was now seeking a means to minimize the effect of pressure rise. Ricardo's explanation of the reason for the non-detonation of his high-turbulent head was[4]:

> This was due not to the turbulence but rather to the fact that, in each instance, the maximum distance that the flame could travel from the spark-plug was exceptionally small.

After much investigation, Ricardo subscribes to the following conclusions, determined by Tizard[5]:

(1) Detonation depends primarily upon the rate of burning of that portion of the charge first ignited; in this he confirms the usually accepted theory

(2) The rate of burning increases very rapidly with a slight increase of the flame-temperature, and whether it will prove sufficiently rapid to produce detonation depends upon the ratio between the rate of evolution of heat by the burning portion of the mixture and the rate of heat loss

(3) The chance that the rate of burning of any portion of the mixture will become so high as to cause detonation depends but little, so far as the practical engine conditions are concerned, upon the temperature or pressure of compression, but rather upon the maximum flame-temperature

(4) For any given mixture-strength, the maximum flame-temperature depends primarily upon the proportion of diluent or exhaust products present. It depends also, of course, upon the compression temperature; but this varies comparatively little over a wide range of compression-ratio, while the variation in the proportion of residual exhaust-products over the same range exerts a much greater influence in diluting and so lowering the temperature of the flame. Thus, a difference of $\pm$ 1 per cent by weight of exhaust diluent will raise or lower the flame-temperature by about 25 deg. cent. (45 deg. fahr.), which is equivalent to a range of compression from 4:1 to 5:1.

In these conclusions, the volume of exhaust diluent is credited as a primary cause of detonation with higher compression, since the volume of the residue decreases appreciably with an increase in compression ratio.

Ricardo explains in this paper that the virtue of tur-

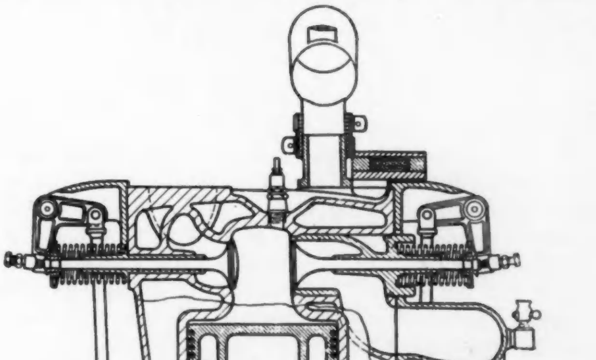


FIG. 2—UPPER PART OF RICARDO TANK ENGINE

[4] See THE JOURNAL, May, 1922, p. 309; TRANSACTIONS, Vol. 17, 1922, Part 1, p. 13; *The Automobile Engineer*, September, 1922, p. 269.

[5] See THE JOURNAL, May, 1922, p. 310; TRANSACTIONS, Vol. 17, 1922, Part 1, p. 14; *The Automobile Engineer*, September, 1922, p. 270.

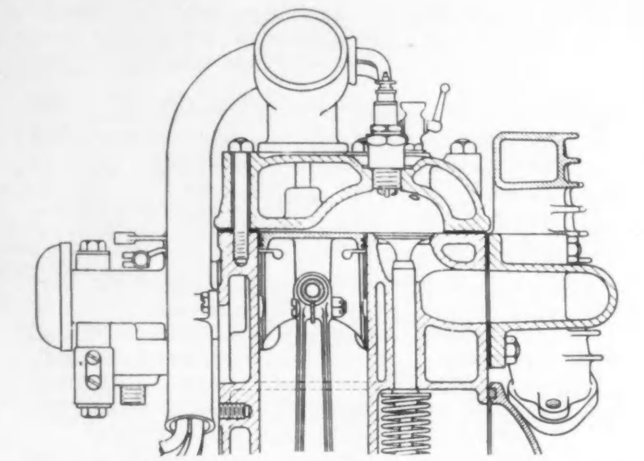


FIG. 3—TOP OF RICARDO TURBULENT-HEAD ENGINE

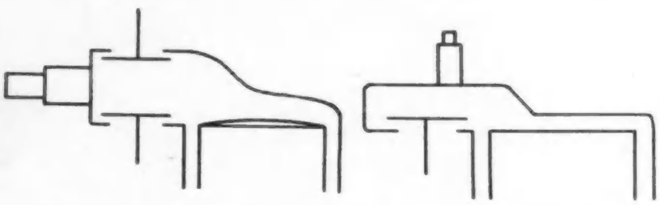


FIG. 4—TWO CYLINDER-HEADS STUDIED BY RICARDO

Both Engines Have Four Cylinders with Two Valves per Cylinder and a Compression Ratio of 4.7:1. The One Shown at the Left Has a Volume of 101.2 Cu. In. and Showed Severe Detonation at 1200 R.P.M. The One at the Right Contained 99.2 Cu. In. and Detonated Very Little at 1100 R.P.M.

bulence is its effective decreasing at the chamber walls of gas films that otherwise would not burn efficiently, due to their being overcooled, and points out that this may be the most important factor in the difference in efficiency between a non-turbulent and a turbulent chamber.

Ricardo's Turbulent Head

Fig. 2 represents a combustion-chamber developed by Ricardo for a tank engine. This engine was unusually free from detonation and operated comfortably on kerosene at a compression ratio of 4.25:1. Following this, the combustion-chamber shown in Fig. 3 was adopted by Ricardo for all L-head engines. He states that this head proved to be the best of any he had tried. It is the famous highly turbulent head. He states with reference to this head that[6]:

> It produces additional turbulence during the compression-stroke and, moreover, the maximum distance from the point of ignition to the farthest point in the combustion-chamber, *the factor which apparently controls detonation beyond all others*, is about the smallest possible.

Fig. 4 shows diagrams of two combustion-chambers classified by Ricardo. Both are of four-cylinder engines having a compression-ratio of 4.7:1. The one at the left has a cylinder volume of 101.2 cu. in. and was said to have severe detonation at 1200 r.p.m. The one at the right has 99.2 cu. in. and was said to show very little detonation at 1100 r.p.m.

A considerable difference exists as regards to sparkplug position, and hence flame travel, although the general contours of the chambers are very much alike. However, there is also a wide difference in piston-head design; therefore, is it not fair to assume a wide difference in clearance-space design in these two heads?

Ricardo's published work began in 1926 to show a reaction to the criticism of his highly turbulent head from this Country. It was too rough. These data were reiterated by him in 1927 in a paper before the Institution of Automobile Engineers, the title of which was Some Notes on Petrol-Engine Development[7]. In this paper he is less the physicist and more the practical engineer. We find such statements as:

> With modern methods of manufacture, the cheapest engine is not necessarily the lightest but rather that which is produced from the least weight of raw material. Multiplicity of parts, provided these parts are small and not unduly intricate, does not necessarily involve expense.

In this paper he gives the three possible antidentonation programs:

(1) The use, in small quantities, of metallic dopes such as lead ethide and iron carbonyl

(2) The use, in considerable quantities, of fuel of high ignition point, such as benzol and other aromatics, naphthenes and alcohol

(3) The design of the combustion-chamber

Ricardo rules out (1) as expensive, poisonous, deleterious to the engine, and good for stunt purposes only. The wide distribution of ethyl gasoline in this Country is an adequate answer to this. The second item, he states, is being carried through by the Shell company, and he points out that one-half a ratio has been gained in compression during the last 7 years. The third possibility has the widest scope.

It appears from his writings that Ricardo had materially progressed in his instrumention. At this time he had a set-up which combines several quartz windows with a stroboscope and an indicator-card machine. Flame time could be established with the quartz windows and the stroboscope. The most important fact established was that, when detonation occurred, a supplementary bright flame appeared at all the windows, but this never occurred until all the windows but the last indicated flame. This established definitely that detonation occurs in the very last gas to burn.

Causes of Roughness Analyzed

In referring to roughness, we read from this 1927 paper[8]:

> Roughness, as ordinarily meant—a harsh feeling and a tendency to cause drumming—is dependent on the one hand on the beam stiffness of the engine as a whole and of the crankshaft in particular, and on the other hand on the rate of pressure rise.

These facts were recognized in several American laboratories during 1925. However, it must be remembered when analyzing English publications of technical material that the patent law in that country exacts secrecy until application is made for a patent, whereas the American patent law allows disclosure for two years before patent application is made. This places men like Ricardo under a tremendous handicap.

I believe that this primary analysis of engine rough-

[6] See THE JOURNAL, May, 1922, p. 316; TRANSACTIONS, Vol. 17, 1922, Part 1, p. 36; *The Automobile Engineer*, October, 1922, p. 299.

[7] See *The Automobile Engineer*, April, 1927, p. 149.

[8] See *The Automobile Engineer*, April, 1927, p. 150.

ness by Ricardo is indicative of the grasp he had on this problem, since it is very much to the point and is all-inclusive. It is obvious that many manufacturers in this Country are not aware today of the fact that powerplant rigidity is essential to combustion satisfaction.

We find in this paper of 1927 comparative results of engines of L-head and overhead-valve types. His conclusions may be summarized as follows:

(1) Unless the stroke is very short, performance is exactly the same for both jobs

(2) Owing to better spark-plug position, the L-head will stand higher compression for the same detonation

(3) To compensate for the more attenuated shape of the L-head, higher turbulence is required for equal performance; hence, the L-head may be rougher. However, this may be overcome

(4) The loss of heat to the walls is negligible.

The curves in Fig. 5 are the result of a splendid bit of instrumentation. The indicator cards are virtually combustion cards, the expansion portion of the curve being eliminated. How roughness can be indicated is seen here. The curves at the left are from an engine that is rough because of the rapid rate of pressure rise. The center curves are from a smooth engine, in which the pressure rise is gradual. The diagram at the right is a comparison of the two engines. These charts indicate the correlated progress of the flame front.

Ricardo has established his roughness comparison on a basis of maximum rate of pressure rise in pounds per degree of crank angle. This method of comparison is also being used by H. L. Horning's organization at the Waukesha Motor Co.

Turbulence as a Cause of Roughness

It is quite evident from Ricardo's work that he was satisfied up to 1927 that turbulence produces roughness, and that this roughness can be pictured by a comparison of the maximum rate of pressure rise in degrees of crank angle.

From our reviewing of Ricardo so far we find that in:

(1919) Turbulence is the most important element in detonation control

(1922) Turbulence is ineffective, but the shortest distance from the spark-plug to the extreme wall of the combustion-chamber is most desirable for detonation control; since this will tend to cut down the pressure rise of the burning portion of the mixture, which is the prime cause of detonation, because of the heat build-up in the unburned portion by being super-compressed

(1927) Ricardo reiterates short flame travel. However, he is fighting roughness. He intimates that roughness can be controlled by controlling turbulence.

We will now examine Ricardo down to date, or in 1929, when he summarizes his own work[9]. Ricardo states that ten years before he had developed a cylinder-head known as the turbulent head, which was designed with the following objectives:

(1) To create additional turbulence during the compression stroke in order to:

(a) Increase the rapidity of burning and so obtain both a greater effective expansion ratio and, at the same time, render the engine much less susceptible to ignition timing

(b) Scour away as far as possible the layer of gas which normally clings to the cool surfaces of the combustion-chamber and is therefore chilled to such an extent as to escape complete combustion, either entirely or until so late in the expansion stroke as to be of little value

(c) Reduce the tendency to detonate by keeping the unburned gas in rapid motion, thus enabling it the more readily to get rid of the heat of compression by the oncoming flame front and at the same time to break up that flame front

(2) To reduce the length of flame travel from the sparking plug to the farthest point in the combustion-chamber by rendering inoperative, so far as detonation is concerned, the part of the combustion-chamber over the farthest side of the piston. This was done by the piston coming into such close contact with the head that the gas between these two relatively cool surfaces was so chilled as to avoid detonation

(3) To keep the flame travel as short as possible by placing the sparking plug in a central position

(4) To reduce to the minimum the surface; volume ratio, and therefore the heat loss during combustion, though this latter is relatively small.

It is plainly to be seen that Ricardo has expanded his original objectives for the turbulent head. The most significant statement here is in (2) "This was done by the piston coming into such close contact with the head that the gas between these two relatively cool surfaces was so chilled as to avoid detonation."

Thus an antidetonation function is definitely

[9] See *The Automobile Engineer*, July, 1929, p. 257.

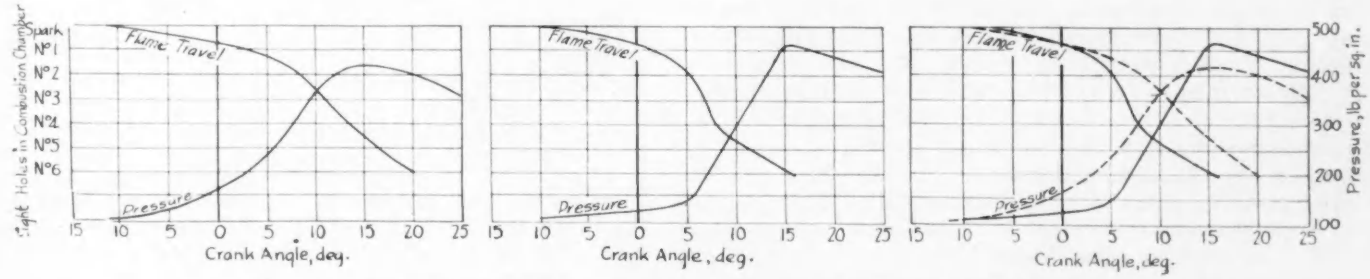


Fig. 5—Indicator Cards Showing Rough and Smooth Combustion

Curves at the Left Are from a Smooth Engine; Curves in the Center Are from a Rough Engine, and the Two Sets of Curves Are Combined at the Right

TABLE 1—EFFECT OF PISTON-HEAD CLEARANCE ON HIGHEST USEFUL COMPRESSION-RATIO (RICARDO)

Head	Clearance between Piston and Cylinder-Head, In.	H.U.C.R., Using Shell No. 1 Gasoline
A	0.022	6.9:1
B	0.085	6.8:1
C	0.147	5.67:1
D	0.210	5.48:1
E	0.272	5.37:1

ascribed to the clearance space that has existed in the earliest of Ricardo's combustion-chambers.

We read from the 1929 paper[10]:

> That, so far as detonation is concerned, the clearance between the piston and cylinder-head in the "inoperative" portion is the main determining factor, and is critical.

Ricardo has gone a long way from turbulence and short flame travel when he definitely refers to the clearance space as the "inoperative portion" and states that it is the main determining factor, and is critical.

To show how critical this clearance space is, he offers the information shown in Table 1. Why Ricardo calls this clearance-space thickness critical is not quite clear from his data, since the usual practice in this Country for the clearance space is one gasket thickness (0.045 in.), and he indicates practically no difference in useful compression-ratio between one-half a gasket thickness (0.022 in.) and two gaskets (0.085 in.) in clearance-space thickness, a difference of 300 per cent. To obtain an appreciable loss in useful compression-ratio, according to Table 1, we should have 0.147-in. thickness of clearance space, or the equivalent of three gaskets. This is most certainly far from present American practice, although perhaps in England the practice may be otherwise.

Influence of Flame Travel

Spark-plug position and its relation to detonation is illustrated by Ricardo in Fig. 6. He has always recommended that the plug be located somewhere near the center of volume, slightly favoring the exhaust valve. He preaches against the exhaust-valve center as a location for the spark-plug, since the additional flame travel involved will decrease the allowable compression-ratio by promoting detonation. From the table accompanying Fig. 6, the loss in compression ratio shown is 0.22 ratio between positions *A* and *B*, yet with 0.147-in. depth of clearance space the loss is indicated as 1.2 ratios. Obviously, if increasing the flame travel to the extent indicated from the center of volume to the exhaust valve makes a difference of 0.22 ratio and the clearance space variation can make a difference of 1.2, as indicated in Table 1, then it is the clearance space and not the flame travel that is the most important factor, other factors being contributory but negligible.

Referring again to Fig. 6, we note that maximum flame travel from position *C* is the same as from position *B*, ignoring what Ricardo designates as the inoperative portion of the combustion-chamber, yet with spark-plug at *C* we lose 0.3 compression ratio. This condition could scarcely prevail if flame travel alone controlled detonation. We believe that it is the interference with the proper functioning of the clearance space that causes this loss in useful compression-ratio. This is our first common factor, and we will trace it through the works of the other two investigators as we proceed.

Ricardo's tank engine, shown in Fig. 2, was cited in 1922 as an early success in the elimination of detonation. The head of this engine, which operated well on kerosene, incorporates the finest possible clearance space, since the clearance has a broad area and makes use of the coolest part of the piston, the entire portion adjacent to the cylinder wall. This clearance space undoubtedly was the most important factor in his success with this engine. Being a tank engine, roughness was probably overlooked.

Continuing our review, we find evidence through his publications of 1929 that Ricardo is perfectly willing for one reason or another to give up at least in part every one of his antidetonating elements except the clearance space. This we will show later.

That the clearance space is uppermost in Ricardo's mind in his 1929 publications is obvious from his remarks[11], which were as follows:

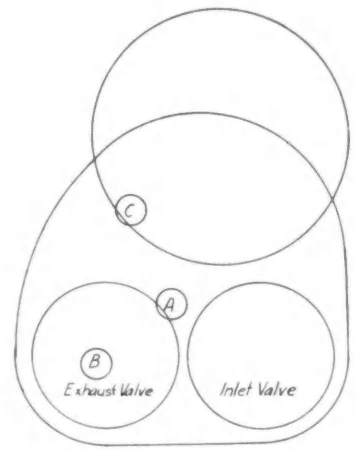


FIG. 6—INFLUENCE OF SPARK-PLUG POSITION (RICARDO)

Position of Spark-Plug	*A*	*B*	*C*
Ignition Advance, deg.	17.6	19.8	23
H.U.C.R. on Shell No. 1 Gasoline	5.87:1	5.65:1	5.3:1
Full-Throttle Performance, Corrected to 5:1 Compression-Ratio			
Brake M.E.P., lb. per sq. in.	111.9	109.7	110.5
Fuel Consumption, pints per b.hp-hr.	0.552	0.577	0.577

> It seems quite clear that detonation is initiated only at the extreme end of the flame travel, due to the compression of usually some quite small portion of the unburned charge by the approaching flame; whether or not detonation will take place with any given fuel depends upon whether this unburned gas can get rid of its heat to the surrounding walls at a sufficient rate. This in turn depends upon:
>
> (1) The speed of the oncoming flame, which tends to increase very rapidly as it travels outwards from the point of ignition and therefore, in effect, upon the length of flame travel
>
> (2) The temperature of the surfaces surrounding the residuum of unburned charge
>
> (3) The degree of turbulence. This would at first sight appear to have little or no influence for, while on the one hand turbulence increases the speed of the oncoming flame, on the other hand it increases to an almost equal extent the facilities of the unburned portion for getting rid of its heat by convection, conduction, and so forth
>
> (4) The area and temperature of any very hot surfaces within the combustion-chamber, such as the exhaust-valve head, which cause local surface combustion during the suction and compression strokes and, in so doing, raise slightly the whole temperature cycle.

[10] See *The Automobile Engineer*, July, 1929, p. 259.

[11] See *The Automobile Engineer*, July, 1929, p. 258.

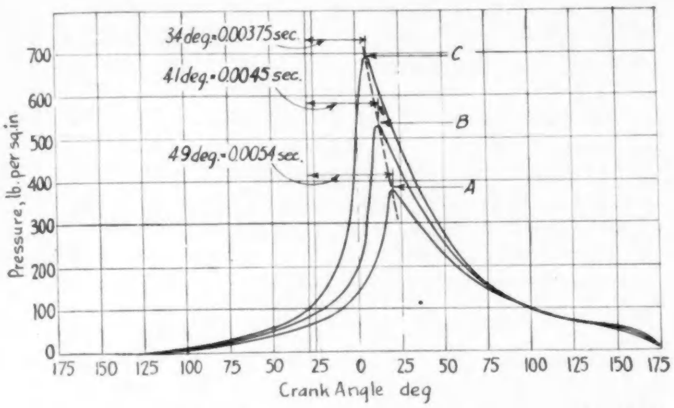


FIG. 7—RELATION BETWEEN COMPRESSION AND BURNING TIME

	Compression Ratio	Indicated M.E.P., Lb. Per Sq. In.
A	4:1	120
B	5:1	136
C	6:1	146.5

Here Ricardo again reiterates short flame travel, but shows interest in the temperature of the metal at the clearance space. Also we find him again flirting with turbulence, although he admits it does about as much good as an aid to lowering temperature as it does harm in increasing the pressure rise.

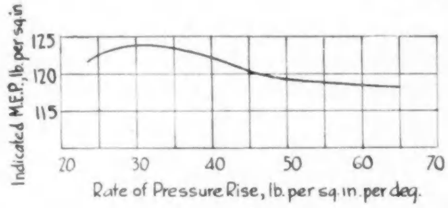


FIG. 8—EFFECT OF RATE OF PRESSURE RISE ON POWER

We shall now temporarily leave the subject of detonation, to follow Ricardo through his roughness investigations. He writes[12]:

Briefly, the more recent experiments have shown:

(1) That the rate of burning depends primarily upon the degree of turbulence and may be expressed in terms of increase of pressure per degree of crank angle. . .

(2) That to a secondary extent the rate of burning depends upon the compression ratio; the higher the compression the more rapid the burning and therefore the less need for turbulence. . .

(3) That at any compression ratio the best power output and efficiency are obtained on full load when the rate of pressure rise is approximately 30 lb. per sq. in. per deg. of crank angle, but that at light loads a somewhat greater degree of turbulence is desirable. . .

(4) That in the so-called "turbulent" head, turbulence is set up to an almost equal degree by:

(a) the initial velocity through the inlet valve and

(b) the velocity through the restricted throat during compression. It is intensified also by the final ejection just prior to ignition of the gases entrapped between the piston and the cylinder-head. . .

(6) That turbulence . . . increases proportionately with increase of speed so that the relationship of rate of pressure rise to crank angle remains substantially constant throughout the whole speed range of the engine. . .

We reproduce herewith some excellent data that Ricardo uses to support the foregoing observations. Fig. 7 shows how the burning time is shortened by the compression ratio. This chart indicates a decrease of 40 per cent in pressure-time between 4:1 and 6:1 compression-ratio. The chart in Fig. 8 is characteristic of Ricardo. It points out that turbulence has a critical value and is used to support item (3). Fig. 9 includes three indicator-cards of an engine running respectively at 800, 1200 and 1800 r.p.m. The maximum rate of pressure rise is seen to be the same for all speeds, supporting Ricardo's contention in item (6).

We cannot help but admire Ricardo for his unexcelled illustrations. They are mute evidence of the tremendous amount of work being done by him and his tireless organization.

The Shock-Absorber Head

We now come to the latest type of Ricardo head, known as the "shock-absorber" head, shown in Fig. 10. This head is the result of his study of turbulence control to obtain smoothness. In discussing this phase of his work, Ricardo points out that[13]:

(1) A high degree of turbulence does not increase the maximum pressure but does influence the rate at which this maximum pressure is attained

(2) Rapid rate of pressure rise, with its subsequent sudden application of pressure, causes springing of the powerplant parts, resulting in roughness. This roughness determines the limit of

[12] See *The Automobile Engineer*, July, 1929, p. 258.
[13] See *The Automobile Engineer*, August, 1929, p. 284.

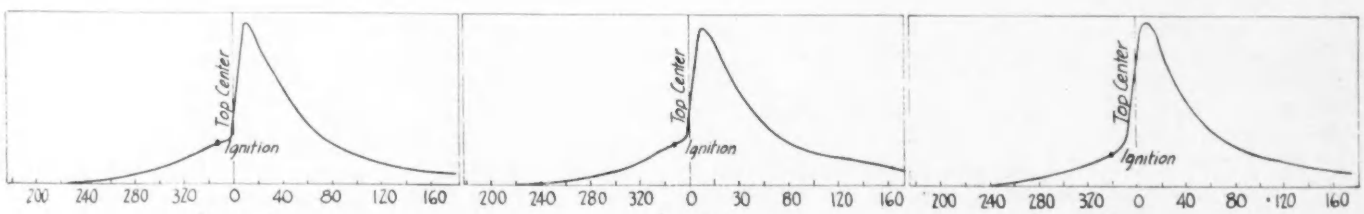


FIG. 9—EFFECT OF ENGINE SPEED

	Speed, R.P.M.	Ignition Advance, Deg.	Maximum Pressure, Lb. per Sq. In.	Detonation
Left Diagram	800	10	438	Slight
Middle Diagram	1200	13	446	None
Right Diagram	1800	21	442	None

All Cards at Full Load with Maximum-Power Mixture. Pressure Rise Is 32.5 Lb. per Sq. In. per Deg. in Each Case

the degree of turbulence which may be employed

(3) The degree of turbulence which a powerplant can sustain without roughness is a measure of that powerplant's rigidity

(4) A well-designed engine will operate smoothly with a pressure-rise rate of 30 lb. per degree of crank angle, and only an exceedingly stiff engine will be smooth at 35 lb. per deg.

From the foregoing it is intimated that the maximum pressure is not important in its effect on roughness, and that the maximum rate of burning is the most important factor. Since turbulence affects only the rate of burning, Ricardo believes it to be the proper

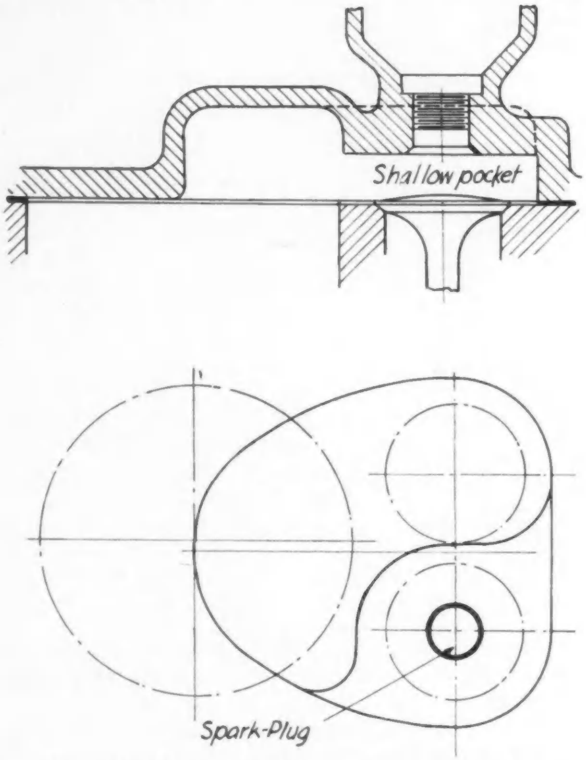


FIG. 10—RICARDO'S "SHOCK-ABSORBER" HEAD

means of roughness control. He argues that, if this very rapid rise of pressure is delayed somewhat and the initial pressure is applied gradually, the following or final pressure rise may be very rapid without any trace of roughness. He uses the analogy of a camshaft ramp which he maintains will operate silently with a very high acceleration provided the take-up of back-lash is gradual.

The comparison is unfortunate for his argument since we are aware that, although a camshaft with the gradual take-up will operate without noise, it may cause the valve spring to surge and the camshaft to deflect unduly. I believe that the same is true of the pressure rise, and that a gradual inflammation with a very rapid finish will be rough because the rapid portion will act to deflect the mechanism, as in the camshaft. I believe a constant acceleration to be ideal in the rate of pressure rise.

The spark-plug is placed in the "shock-absorber" type of head in a shallow pocket which is designed to include about 15 per cent of the charge. This portion Ricardo considers as stagnant, since it is relatively free from turbulence. The remaining portion he maintains can be burned at 50-lb. pressure-rise per crank degree with less roughness than a previous head with a rate of 30 lb. This is illustrated by him in Fig. 11, which is used by Ricardo to demonstrate the difference between a rough and a smooth-running condition. The maximum rate in these curves is shown to be the same. The pressure rise per degree of crank angle is given as 51 lb. per sq. in. for *A*, which is very rough, and 53 lb. per sq. in. for *B*, which is smooth.

Ricardo's Theory Questioned

Examination of these curves shows that they disagree with Ricardo's own theory. If a gradual pressure rise is to bring about smoothness, then curve *A* should result in a much smoother engine, since the pressure rise is extremely gradual from the point of ignition to top dead-center. On the other hand, the *B* curve appears to be considerably more progressive and at top dead-center has risen quite a bit. My disagreement is not with the results, because our experience over a period of years confirms the fact that an engine with the *A* curve will be rough, and one with the *B* curve will tend to be smoother. However—in view of the fact that Ricardo shows in his charts, reproduced in Fig. 8, that a time-pressure of 30 to 40 lb. per sq. in. per degree of crank angle is most effective and efficiency is lost above this point—we do not understand his efforts to obtain 50 lb. per sq. in. and even more in

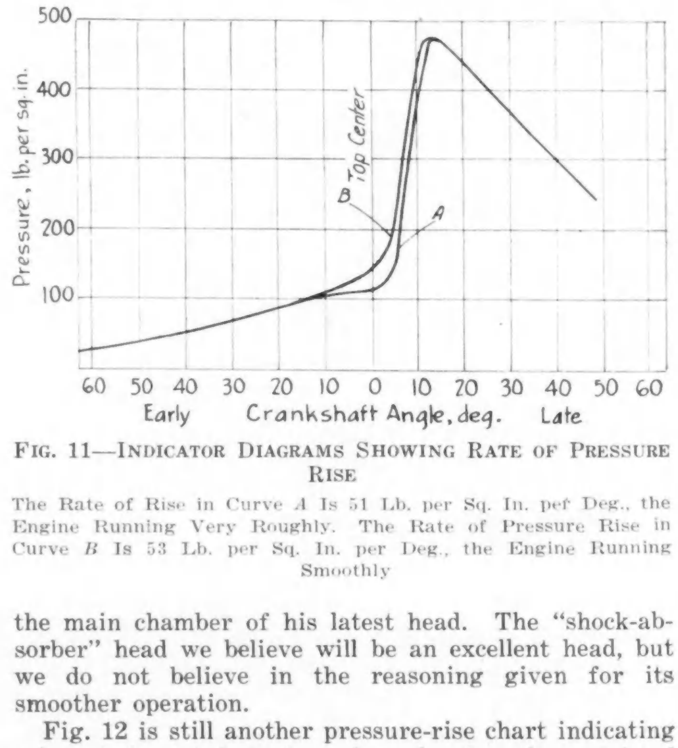


FIG. 11—INDICATOR DIAGRAMS SHOWING RATE OF PRESSURE RISE

The Rate of Rise in Curve *A* Is 51 Lb. per Sq. In. per Deg., the Engine Running Very Roughly. The Rate of Pressure Rise in Curve *B* Is 53 Lb. per Sq. In. per Deg., the Engine Running Smoothly

the main chamber of his latest head. The "shock-absorber" head we believe will be an excellent head, but we do not believe in the reasoning given for its smoother operation.

Fig. 12 is still another pressure-rise chart indicating a lag of about 4 deg. of crank angle when the restricted area is over the inlet valve instead of over the exhaust valve. This diagram is much better than Fig. 11 for the purpose of the acceleration analysis which I will make later.

In describing this head Ricardo makes the following statement[14]:

> From the point of view of detonation, although the sparking plug is no longer centrally situated, the

[14] See *The Automobile Engineer*, August, 1929, p. 285.

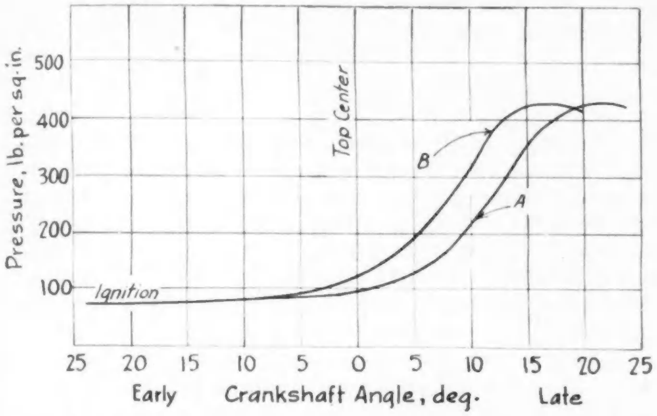


FIG. 12—RATE OF PRESSURE RISE IN SHOCK-ABSORBER HEAD
Curve A Is with Pocket over Inlet Valve and Curve B with Pocket over Exhaust Valve

"shock-absorber" type of head is very slightly better than the ordinary turbulent type because, so far as detonation is concerned, the effective length of flame travel is little more than that from the open mouth of the pocket to the farthest point in the combustion-chamber.

From the foregoing we find that "short flame travel" has gone to join turbulence. The "shock-absorber" head, with its greater distance between spark-plug and the extreme walls of the combustion-chamber, detonates less than the ordinary turbulent type. This is in spite of his explanation that the restricted area does not count in flame distance, a statement to which we cannot subscribe.

When the clearance space is opened up to 1/4 in. we know well that it does count, and I am sure that the restricted area of the "shock-absorber" head must be deeper than the valve lift, and therefore will be an operative part of the chamber. I believe that, for most L-head engines, this restricted area will of necessity be at the exhaust valve, or we may find that the last gas to burn is in the exhaust pocket.

The clearance space is still a part of the "shock-absorber" head, and I believe that I am justified in my previous statement that the clearance space is the most important element in detonation control, and all other elements, though contributory, are relatively negligible, and that this clearance space is the one common factor in all combustion-chamber contributions.

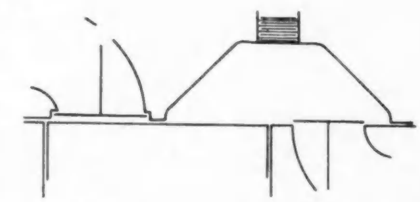


FIG. 13—RICARDO HEAD FOR HIGH POWER

Controlling Area of Flame Front

The Ricardo "shock-absorber" head, due to the volume reduction in a portion, introduces into Ricardo's work a chamber wherein the area of mixture exposed to the flame front varies and can be controlled by the extent of the chamber involved in the variation. The spark-plug is located in a relatively shallow portion. This condition is common factor No. 2, and must be borne in mind in comparing the works of the others.

Fig. 13 is a new type of combustion-chamber for high-power engines. Primarily this chamber is intended to have a pent-roof contour similar to the highly efficient overhead-camshaft type that has been fairly well standardized in aircraft.

Ricardo states that this chamber is more compact than the ordinary turbulent head, and we believe that for this reason it would be entirely too rough for passenger-car engines. However, he points out that it may be modified by the use of a "shock-absorber" pocket. This chamber is a modification of the F-head chamber, which has the greatest engineering potentialities of any chamber.

In this Country, one of the largest manufacturing companies adopted the F-head engine as a new discovery a few years ago, at the same time that it was discarded by another important company. Neither of these companies has attempted to exploit its possibilities. Surely this valve arrangement, with its attendant cooling possibilities, is most ideal, especially for an eight. I have always believed that the ideal passenger-car engine can be made with this type of chamber, because of the possibility of controlling the area of the flame front, its volumetric advantage, and its detonation-control possibilities.

This concludes my direct review of Ricardo's combustion-chamber work. I have endeavored to approach Ricardo and his work with the utmost respect, which I am happy to acknowledge to this great engineer.

PART 2—WHATMOUGH'S THEORIES SCRUTINIZED

The next review must logically be of Whatmough, a fellow countryman of Ricardo. Whatmough is not the engineer that Ricardo is. He lacks Ricardo's practical experience. Whatmough is essentially a physical chemist who, by virtue of his analytical ability, has branched out and applied his energies to the internal-combustion engine.

Whatmough is not obvious, he is difficult to understand. Perhaps the reason lies in his own explanation, offered in conversation with me during his recent visit to this Country, when questioned on the highly technical nature of his writings. He stated that he wrote primarily for himself and quite often had no idea how far afield his pen would take him, since he used this method to develop his thoughts.

Whatmough presented a paper[15] at the 1929 Semi-Annual Meeting of the Society at Saranac Lake, which was discussed by Janeway and me[16]. We are able to analyze that paper, because he has made a distinct effort therein to present his theorems in a language more understandable than is usual for him, and it will be the leading subject matter of this analysis.

Whatmough's Principles Stated

Whatmough states his case in the following[17] principles, which he considers a simple synopsis:

(1) Heat is generated by burning air carburated with hydrocarbon vapor, the evolution of energy occurring during the chemical reunion of atoms.

[15] See S.A.E. JOURNAL, September, 1929, p. 249; TRANSACTIONS, Vol. 24, 1929, p. 115.
[16] See S.A.E. JOURNAL, October, 2929, p. 383; TRANSACTIONS, Vol. 24, 1929, p. 138.
[17] See S.A.E. JOURNAL, September, 1929, p. 250; TRANSACTIONS, Vol. 24, 1929, p. 116.

(2) Flame travels just as fast as energy becomes available to fire fresh charge.

(3) The flame front is a surface extension of inflammation during normal combustion.

(4) Spontaneous combustion, or auto-ignition, is due to combustible becoming heated throughout its volume to its self-ignition point.

(5) The flame thrust is smooth or uneven or rough according to the timing of the rate of inflammation.

(6) The working parts are stressed in accordance with flame speed.

(7) Regulated burning is characterized by a steady or steamlike propulsion.

(8) Shock loading of piston and rough running result from unduly rapid pressure-rise.

(9) Engine knock is reaction to high-speed projection of flame, due to autoignition subsequent to spark ignition.

(10) Heating combustible increases flame speed.

(11) Cooling compressed charge slows flame travel.

(12) Overheating part of combustible during compression by flame front may lead to engine knock.

(13) Overheating prior to sparking causes preignition.

(14) Overcooling leads to (*a*) fuel deposition during compression, (*b*) failure to fire and (*c*) quenching of flame after firing.

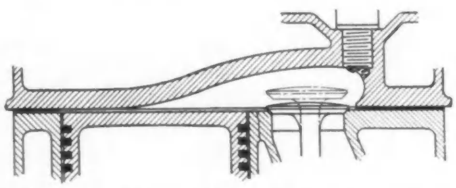


FIG. 14—WHATMOUGH ANTI-TURBULENT CYLINDER-HEAD

Some of the above principles are known and established facts; others are similar to the published principles of Ricardo; and still others are new and must be considered Whatmoughisms, to be credited to or defended by him.

It may be well to remind the reader here that the prime objective of this review is to bring out common factors. Any repetition that occurs is with this point in view.

Items (7), (8), (10), (12) and (13) are in direct agreement with Ricardo. Items (2) and (3) are Whatmoughisms that I have failed to understand. In all probability they have a simple enough meaning, but this meaning is befogged by the wording. Items (4), (5) and (6) are fairly clear; however, agreement with Ricardo and others is lacking. Items (11) and (14) refer to Whatmough's principle of combustion control for smoothness.

With regard to item (4), we have often observed the effect of pre-ignition or self-ignition that occurred directly after regular ignition. This can probably be explained by the critical conditions prior to ignition which, with the smallest upward change in temperature brought on by partial inflammation, will cause a large residue, probably two-thirds of the whole, to burn with the equivalent of spontaneous combustion, since inflammability is faster in this portion than it could be in natural sequence.

Effect of Flame Speed Questioned

Item (5) incorporates a theory of Whatmough's that considers the effect of "flame speed," by which is meant the effect of the actual flame in its progress across the piston. This is again referred to in item (6), wherein it is stated that "working parts are stressed in accordance with flame speed." Whatmough has advanced the thought that, due to the rapidity of flame throughout its motion, and in particular across the portion of the piston exposed to the main part of the combustion-chamber, the piston would be forced over to one side of the bore, opposite to the direction of flame progress, and thus cause piston slap or knock and otherwise unduly wear the engine parts.

Perhaps this might be true if flame progress was separate from pressure rise. However, pressure rise is simultaneous with flame spread, and the effect of the latter can only be small in comparison to the effect of pressure. Further, where flame might tend to move the piston in one direction, perhaps the progress of the pressure might move it in the opposite direction.

Item (9) evidently refers to detonation. Ricardo has already given evidence that when detonation occurs there is a bright flash at all the quartz windows, indicating an inflammatory reaction throughout the whole. Decision as to just what is the mechanism of the resonance we hear as a "ping" will have to be left to the physicists.

Getting down to the bedrock of the clearest statement Whatmough has made in describing his principles of combustion control, we read[17]:

> Cooling and/or warming of the charge is the one sure guide to that balancing of the many otherwise mysterious flow-factors entering into combustion-chamber design. Conclusions deduced from combustion-chamber shape will mislead whenever they do not conform with the *heat control, which is the one decisive factor* in that regulated burning which smooths power output and increases engine efficiency.

Cooling and warming of the charge means cooling the portion that is progressively overheated by the burning portion, and heating the initial portion to burn. Cooling or warming assumes a condition wherein the last portion to burn is being overcooled and requires warming up to obtain efficiency.

I think that, under operating conditions with stabilized water and oil temperatures, overcooling of the last portion to burn is a myth. Increasing the compression ratio would quickly wash out this condition. Whatmough is very certain that his method is the only possible correct means of regulation for smoothness, yet Ricardo is just as emphatic in stating that control of turbulence is the major factor. We shall return to this disagreement.

Antiturbulent Combustion-Chamber

Fig. 14 represents a typical Whatmough combustion-chamber, which is called antiturbulent, inferring that turbulence, as recommended by Ricardo, is the antithesis of what is desired. Whatmough states[18]:

> Turbulence is the theoretical explanation for increase in flame speed by more or less violent agitation of the combustible during the compression stroke. In practice the "turbulent" L-head permits an increase in compression ratio whereby it develops more power. However, its vagaries in regard to roughness of run-

[17] See S.A.E. JOURNAL, September, 1929, p. 250; TRANSACTIONS, Vol. 24, 1929, p. 116.

[18] See S.A.E. JOURNAL, September, 1929, p. 252; TRANSACTIONS, Vol. 24, 1929, p. 118.

ning discount its supposed antiknock properties. Undoubtedly the speeding up of inflammation attributed to turbulence is due to turbulent heating or eddying contact of the unburned charge with heating surfaces.

We know that Ricardo expects to dissipate heat to the wall by turbulence, or agitation of the unburned charge. Whatmough, however, believes that the agitation of the mixture will pick up heat from the walls. This sounds like an impasse, yet obviously both are right. Where the walls are hotter than the mixture, the transfer will be to the mixture; where the walls are cooler, the transfer will be to the walls.

In test work I have observed that, when the water temperature is below normal, performance remains sluggish until the powerplant is warmed up. Undoubtedly the burning is slower because of the overcooling of the charge. We also know that we cannot operate at all times under the ideal temperature. For instance, a powerplant will show a maximum performance around 135 deg. fahr. Since much higher temperatures are found on the road, tests are conducted at 175 deg. fahr. and we all know that a lower performance is obtained under this temperature. However, we usually obtain better economy. The lower performance has been ascribed to a volumetric loss and the increase in economy to improved distribution and perhaps some slight increase in efficiency.

The volumetric loss I presume must be charged to the socalled turbulence during induction; hence, if this element were reduced, induction would be improved. Unfortunately, I do not believe that there is a measurable difference in turbulence due to induction between Whatmough's antiturbulent and Ricardo's turbulent chamber, at least in its effect on picking up heat during induction.

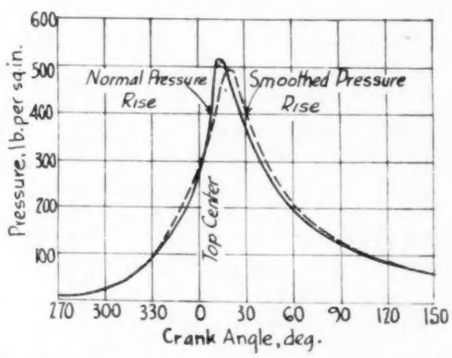


FIG. 15—WHATMOUGH PRESSURE-RISE DIAGRAM

Consideration of the metal temperature under operation would serve to dispose of the question as to the direction of heat transfer between gas and walls during the process of combustion due to agitation, since we know that with water at 175 deg. fahr. the metal temperature, with exception of the center of the piston, varies transversely from 500 deg. near the exhaust-valve seat to 210 deg. at the extreme walls of the main chamber. As we know also that the mixture temperature at the time of ignition is approximately 550 to 650 deg. fahr., there can be very little heat flow either way. However, with the exhaust-valve temperature around 1200 to 1600 deg., according to design and other factors, heat undoubtedly will pass from the valve to the mixture. This condition, however, is local within very narrow limits. The compression of the unburned portion must increase as combustion proceeds, since the pressure of the burning portion to which it is exposed is increasing likewise. It is certain that when this reaches 300 lb. per sq. in. the mixture temperature is much higher, probably between 750 and 850 deg. fahr. or considerably above the metal temperature. Therefore heat will flow from the mixture to the walls regardless of turbulence, except as turbulence may increase the transfer and thus partially aid cooling. In fact, were it not for this temperature difference and heat interchange, Whatmough would be minus a theory. Certainly, if heat transfer works for Whatmough it works for Ricardo.

Fig. 15 is, we believe, a chart of indicator cards. They are very unusual since they are offered by Whatmough to indicate the difference between "normal" and "smoothed" pressure rise. The facts are that neither of these curves indicates a rough condition. The curve for normal is considerably smoother than Ricardo's smooth curve.

It is difficult to be sure from Whatmough's paper whether these curves are actual or synthetic. If not actual they are at least evidence that Whatmough knows how to represent smoothness.

The differences shown in these indicator cards are, according to Whatmough, due to "directional firing, after warming the initial charge." This is accomplished by locating the spark-plug at or in the vicinity of the exhaust valve. This gives the warm initial burning and, if the surface:volume ratio increases as the burning advances, we are firing into a cooler zone. Fig. 14 indicates how this is accomplished in Whatmough's "antiturbulent" cylinder-head.

Claims for Directional Firing

Whatmough claims[19] the following gains from the directional firing that is incorporated in his design:

(1) Reduction of initial lag in pressure rise owing to an increase in flame speed due to charge being heated by the hot exhaust-valve head

(2) Lowering of peak pressure because the flame is continuously progressing toward the cooler zones

(3) Spreading of higher pressure over a wider working range consequent upon delayed burning.

The first of these claims indicates a wide divergence from the aims of Ricardo, who claims an arranged gradual initial pressure rise. However, we should remember that he indicated an actual increase in initial inflammation. Ricardo's "shock-absorber" chamber operates as a precombustion chamber and gives the flame front a healthy start before it strikes the heavy volume. Ricardo's spark-plug with this chamber is likewise over the exhaust valve, since he must avoid the possibility of the heat pocket at the exhaust containing the last portion of the mixture to burn.

Although the architecture of the Ricardo and Whatmough chambers differs widely, their initial principles are the same. Each has a controlled build-up. Ricardo accomplishes his result by modification of the height of the chamber around the spark-plug and Whatmough by placing the spark-plug at the intersection of a wall. This causes the wall to act as a cut-off and controls the area of the initial burning.

Whatmough accomplishes item (3) by the *increase* in thickness of his chamber as the flame front passes over the valve pocket. Ricardo's chamber incorporates the same characteristics, since the volume burned in this chamber is increased rather quickly at the end of

[19] See S.A.E. JOURNAL, September, 1929, p. 251; TRANSACTIONS, Vol. 24, 1929, p. 117.

his "shock-absorber" pocket. However, there is a marked difference between the chambers after these two primary burning stages, as indicated in item (2). By cooler zones is meant cooler metal and areas of greater surface:volume ratio, and therefore smaller *volume* zones. The Ricardo chambers on which we have data do not indicate this condition, yet he may accomplish this by lengthening and tapering the plan of his chamber.

Thin Clearance a Common Feature

The last stage of the burning is also similar for both chambers, since both incorporate *thin clearance spaces*. Thus we see wide divergence of stated principles and close actual principles with exception of the point of doubt in the design of the last portion of Ricardo's main chamber.

Whatmough has laid great stress on the evil of overcooling and cites as an example a comparative test made on similar cylinder-heads, one being made of aluminum and the other of cast iron.

The aluminum head showed less power and economy and less detonation. This difference in economy was credited to flame quenching, which claim Whatmough supports by pictures of the two heads showing heavy carbon deposits on the aluminum clearance-space wall. However, if the compression were raised for the aluminum to the same detonation point as the iron, the difference in power and economy would be made up and the higher temperature of the last gas to burn would be sufficient to overcome the temperature drop.

Another procedure would be to decrease the effectiveness of the clearance space. Ricardo has offered data that indicate how the effectiveness of the clearance space can be modified.

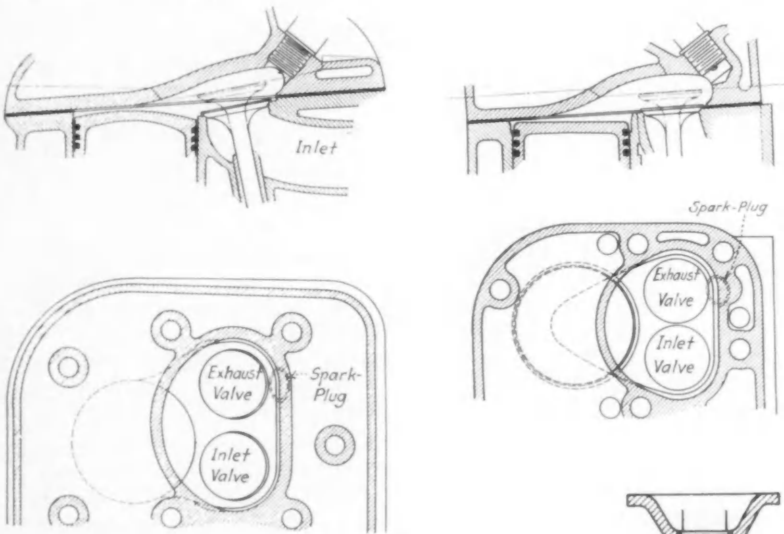
Under stabilized warmed-up conditions, Whatmough will have difficulty in finding evidence of flame quenching to any great extent unless this condition is deliberately built in. Fig. 16 shows various designs of Whatmough cylinder-heads. Note that every one of these designs incorporates a thin clearance space, yet he does not recognize any virtue in the clearance space.

Ricardo in his latest work acknowledged the value of the clearance space, which he has used since before 1919. Whatmough states[18] with reference to this important item:

> The quenching of the flame in the cooled shallow clearance space contradicts its supposed anti-knock action. The engine could easily be made to knock despite the charge compressed into the clearance space being unable to burn under circumstances where it is supposed to self-ignite.

We presume that Whatmough obtains his contradiction here because of the facts that Ricardo has repeatedly referred to this clearance space as the inoperative portion, and that if inoperative, it could not self-ignite. However, we have seen in this review that Ricardo has added quotation marks to his term "inoperative" and has given specific values for various thicknesses of the clearance space in compression-ratio increase. This clearance space is not "inoperative" and

[18] See S.A.E. JOURNAL, September, 1929, p. 252; TRANSACTIONS, Vol. 24, 1929, p. 118.



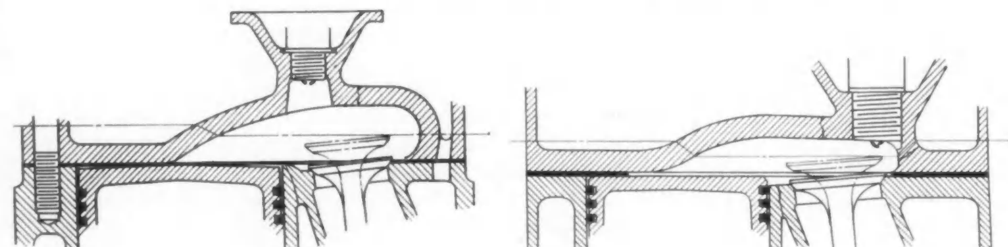


FIG. 16 — VARIOUS WHATMOUGH CYLINDER-HEAD DESIGNS

Whatmough must be well aware of this fact or he would not include it in all of his designs as shown previously herein.

Whatmough's Superefficiency Head

Whatmough has disclosed a new type of head which he calls the superefficiency combustion-head. This is shown in Fig. 17. This chamber does not incorporate a shallow clearance space. However, in place of it we find an enlarged inlet valve that will mechanically cool the last gas to burn. Whatmough expects to do better than the clearance space, since with this design he intends to incorporate a variable water circulation wherein relatively cold water will surround the exhaust valve and hot water will surround the inlet valve and the zone of the last gas to burn. This design incorporates other features to permit greater volumetric efficiency; however, they are outside of our review.

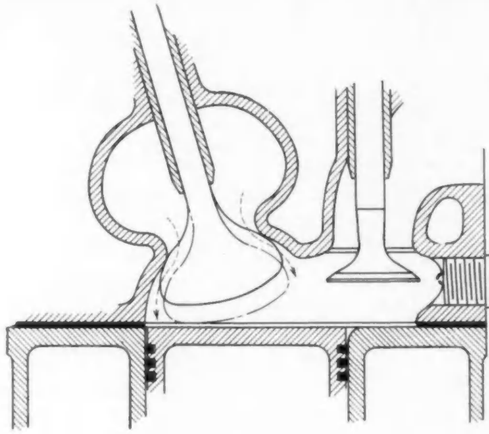


FIG. 17—WHATMOUGH'S SUPEREFFICIENCY COMBUSTION-HEAD

We have always believed, as previously stated, that the chamber of Fig. 18 represents a greater engineering potential than any design of chamber that has been submitted to date.

If Whatmough is to be consistent and be enabled to warm up the last gas to burn it is essential that he deal with a varying water temperature in conjunction with his cylinder-head work, since the opportunity for combustion control by temperature is limited to more or less cooling with the surface:volume ratio and a constantly decreasing metal temperature except at the exhaust valve which is the ignition point. However, Whatmough alone has found it necessary to warm up the last gas to burn.

We have so far not mentioned the streamlining of Whatmough's chamber. Improvement of volumetric efficiency by design of flow lines is not new, and there is more than one way of doing this. Nevertheless this feature of Whatmough's is a distinct improvement over many designs where the effect on filling has been overlooked. Streamlining the throat of the chamber is an old American practice, although when the throat is large enough it is difficult to show improvement. Streamlining around the valves or its equivalent is not being done generally; however, its application will always show improvement.

Whatmough is right again in his attitude toward the unnecessary heating of the exhaust valve. Good results have been accomplished by one American manufacturer by following up a Whatmough suggestion along these lines.

Variation in Heat Exchanges

Whatmough himself in a recent letter defines his position relative to Ricardo and Janeway, as follows:

> The main difference between myself and other combustion-chamber experts is that my principles concern *variation in heat exchanges* and hence cannot be tied down to a single specific feature, such as the turbulence of Ricardo, or the clearance space (cooling) effect of Janeway.
>
> This does not mean that Ricardo and Janeway are wrong. Indeed, their ideas have useful application, but no single factor can be a cure-all for the detonation evil.
>
> Moreover, stressing a single factor leads to unbalance in the study of heat effects and hence in engine design. For example, excessive turbulence leads to autoignition, whilst undue overcooling in clearance space will cause flame quenching and power loss.
>
> As you are aware, I have abandoned the thermodynamics used as a conventional basis of heat-engine theory in favor of the physico-chemical aspects of heat development.

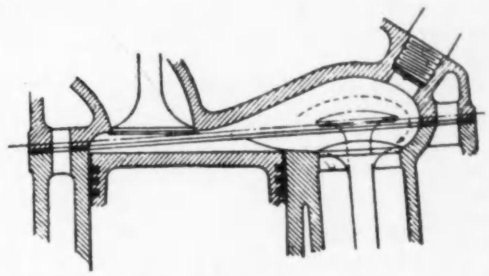


FIG. 18—F-HEAD DESIGN BY WHATMOUGH

Whatmough maintains that either turbulence or clearance space can be carried to injurious extremes. I doubt, however, whether this is true within the very wide limits of regular practice. I have never seen a case of effective flame quenching under *normal* operation, or a case of autoignition that can be charged directly to excessive turbulence.

Physico-chemical considerations alone are the basis for Whatmough's development progress. He teaches that "thermo-equilibrium" must exist for every stage of flame propagation. This equilibrium is affected by every element capable of receiving or transferring heat.

Whatmough maintains there is a constant heat interchange between walls and mixture after ignition, and this interchange is the prime factor in combustion control. When the thermo-equilibrium is established low in the scale of temperature, flame speed will be slow. This equilibrium may be sufficiently low to lower operating efficiency, or may be high enough to cause detonation.

Obviously, local hot-spots at the walls of the combustion-chamber will tend to establish the thermo-equilibrium at a high point, then flame speed will be rapid until cooler sections are traversed and the thermal balance is lowered, with a resultant diminished flame speed. Whatmough has endeavored to establish this ideal by differential water-cooling in combination with a variation of surface:volume ratio of the combustion-chamber wall. The latter increases as flame progresses.

It is very difficult to disagree with Whatmough as to the effectiveness of heat transfer between the contents of the combustion-chamber and its walls as a means of combustion control. In fact, this principle is recognized by all today in the application of the clearance space to detonation control. Here we deliberately provide a very high local surface:volume ratio, which acts to reduce the temperature of the last gas to burn.

Thus we admit the general principle of Whatmough's method, yet we hesitate to accept this principle in full.

Designers Need Tangible Information

I am speaking now for the designing engineer who, by the nature of things, is forced to deal with fundamentals in the concrete. Whatmough appears to us mostly in the abstract. It is true that we are gradually arriving at a better understanding of Whatmough and his ideals; nevertheless, the purely physico-chemical must be backed up with something more than the statement that the present accepted principles of thermodynamics are to be superseded by the fundamentals of physical chemistry.

A job that lies before Whatmough is an explanation of the fundamentals of physical chemistry and how they are applied to definitely control combustion-chamber shapes, which information should be expounded in such terms as to permit understanding by the bewildered designer. Thus Whatmough can earn the blessings of the multitude.

Janeway, as I shall show, proportions his chambers by proportioning the volume progressively burned. His proportion is based on the fundamentals of thermodynamics, combined with the latest in experimental data. This is a tangible procedure. Perhaps to Whatmough his own methods are just as tangible; however, as an engineer, I still ask, "How?" We know that Whatmough and Janeway have evolved chambers that are non-compact. Janeway uses volume progressively burned as a proportioning means and, incidentally, incorporates a gradual increase of surface:volume ratio, thus obtaining advantage of a varying heat transfer. Whatmough claims the varying heat transfer as a proportioning means and, incidentally, incorporates in all of his chambers a variation in volume progressively burned.

Undoubtedly both of these factors are important and bear a definite relation to each other, but we will never know what this relation is if we, like Whatmough, abandon thermodynamics for physical chemistry, even if we knew how.

Differential Water-Cooling

Whatmough has detailed his ideas on Differential Water-Cooling in a recent paper[20] which is a dissertation on controlling the water flow in the water-jacket of the cylinder-head. He points out the necessity of designing flow into the casting, forcing adequate circulation around the exhaust-valve pocket and spark-plug. His illustrations are reproduced in Figs. 19 to 22.

Fig. 19 indicates adequate circulation because of central spark-plug location. Fig. 20 indicates poor circulation because the spark-plug boss is tied to the stud boss. Fig. 21 shows Whatmough's correction, permitting "plug location well over the exhaust valve, with adequate water circulation." This construction is well worth bearing in mind if the plug location is to be as indicated. Fortunately, we have never found it essential or even desirable to locate the plug in this extreme position. In fact, we have found it necessary to place the plug nearly midway between the valves to eliminate poor idling and high-speed missing.

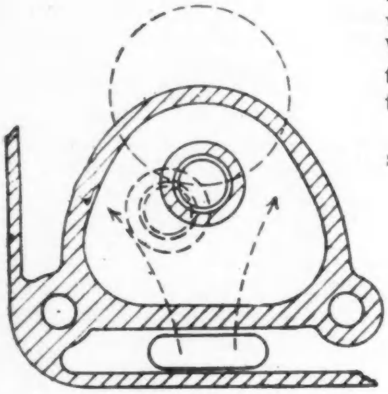
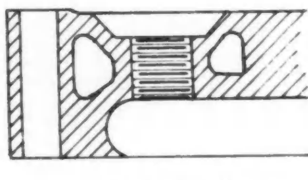


FIG. 19



Section A-A-A

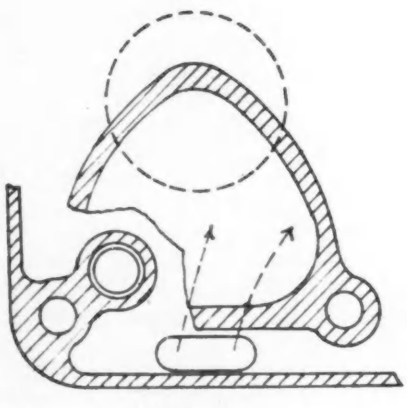


FIG. 20

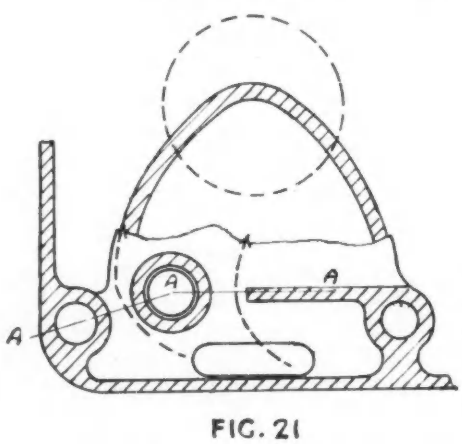


FIG. 21

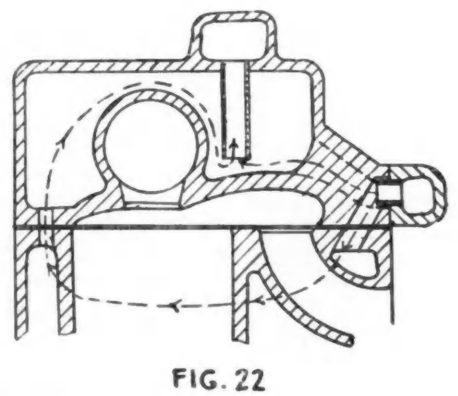


FIG. 22

WHATMOUGH'S IDEAS FOR DIFFERENTIAL WATER-COOLING

Fig. 19—Central Spark-Plug Allows Adequate Circulation
Fig. 20—Location of Spark-Plug Boss Impedes Circulation
Fig. 21—Modification of Fig. 20 to Allow Circulation
Fig. 22—Controlling Circulation in F-Head

Janeway has confirmed this plug location in his investigations. Unfortunately, the plug position must be compromised to meet various conditions. We must consider smoothness, detonation, high-speed firing and idling, and my experience coincides with Janeway's recommendations.

Fig. 22 indicates that Whatmough has not overlooked the possibilities of the F-head with the overhead inlet valve located in the clearance space, and he believes

[20] See *The Automobile Engineer*, February, 1930, p. 53.

that, with a cool inlet valve in this location, the shallow clearance space is unnecessary. He goes further, as can be seen in Fig. 22, and provides a definite circulation of hot water around this area. We do not agree that this is an essential feature from the standpoint of combustion, but it is necessary for an entirely different purpose, as we shall see later. There appears to be a general agreement among the experts that the F-head incorporates the maximum of engineering potential.

Whatmough has laid great stress upon the necessity of good distribution as an important preliminary to combustion-chamber design. Ricardo has likewise repeatedly mentioned this in his earlier works, and we find today that Janeway is engaged in a study of this illusive virtue.

Securing Uniform Distribution

Obviously, we cannot progress with chamber design and have mixture conditions different in each cylinder, hence equal distribution is an essential. In a letter to me, Whatmough states, with reference to distribution:

> I prefer to stabilize the mixture during carburetion by supplying in the air intake the requiste heat to vaporize the petrol (the fuel being finely subdivided by a super-spray carbureter).
>
> It can be definitely stated that bench and road tests have confirmed the practical merits of this procedure. Thereafter the distribution question merely concerns the prevention of heat loss from the stabilized mixture.
>
> The internal induction problem in a petrol engine simplifies into delivering the same amount of stabilized charge to each cylinder. This in reality is a carburetion and distribution problem but I have always emphasized (and still do) that this is the essential preliminary to an efficient and smooth running engine.

These statements incorporate three interesting points:

(1) Whatmough's emphatic stand on distribution

(2) Whatmough's belief in heated air (with a temperature rise proportioned to demand) to stabilize distribution

(3) Whatmough's desire that the mixture temperature shall not be disturbed during its passage through the induction system.

Item (1) I have dwelt on in the foregoing. Item (2) does not agree with American practice, and from my own experience I am sure that heated air alone, regardless of control, would be inadequate in this Country, where atmospheric temperature varies from −30 to +110 deg. fahr.

Item (3) reveals the chief reason why Whatmough warms the zone in his combustion-chamber where the last gas burns. It is because his induction system is in this locality, and that must be kept warm or distribution will fail because of condensation.

In our work on distribution we have found a new difficulty. This is a distribution variation between like products. In working out distribution problems we are obliged to work with difficulties as they exist or present themselves in a given construction, and the problem becomes complex when engines of the same design vary as much as 18 per cent.

A stabilizing element is needed. Heat will serve; but in such quantities as to be useless where power and efficiency are required. High velocity through the induction system is very beneficial, since this has a tendency to mechanically dry the system. However, small manifolds and high engine-speeds do not go well together.

Temperature Effects During Compression

Whatmough maintains in his letter that experts pay insufficient attention to the "disturbing effects upon power development which can occur during the compression stroke." He divides these difficulties into two major classes:

(1) Overcooling of the cylinder-walls with low water temperatures, causing fuel deposition

(2) "Overheating in the cylinder" which tends to promote a preburning of the mixture, resulting in "uncontrolled combustion" with excessive detonation and power loss

It is not difficult to agree with Whatmough with reference to (1), since we are all aware that it is necessary to stabilize the water temperature fairly high to obtain fuel efficiency. I believe Whatmough's limits for correct water temperature are too high. He maintains that 140 deg. fahr. is low, and 175 to 195 deg. represents the ideal. We believe 125 deg. is low, and that 160 to 175 deg. is ideal.

Perhaps Whatmough is correct with reference to (2), and that preburning does exist under conditions of overheating. Whatmough, in the letter to which reference has been made, lists the temperature of the residual exhaust gases and the temperature of the walls of the cylinder and chamber as the chief elements responsible for this objectionable preheating of the mixture. Surely in this day no engineer ignores the effect of preheating, and for this reason its consideration should be discounted.

Over-hot exhaust gas and cylinder-walls are usually chargeable to after-burning, which in turn is caused by slow burning or poor combustion. Lean mixtures are usually found at the bottom of this evil, although other causes contribute.

Referring to explosion, Whatmough's letter states as follows:

> The rate of burning should be such that the peak pressure is attained some 10 deg. after top dead-center. This means in practice that the flame speed is some 30 to 60 times the piston speed. A really marvelous feature is that it is possible with a petrol engine to time the peak pressures to within about 0.01 in. of piston travel.
>
> However, it is not generally known that the extra spark advance at high speeds by no means compensates for the increase in piston speed at higher engine speed.
>
> For example, an engine correctly timed at 10 deg. spark advance at 600 r.p.m. will have a flame speed in a certain engine, say of 100 x 140 mm. (3.937 x 5.512 in.), some 60 times the *average* piston speed, whereas with 30 deg. spark advance at 3000 r.p.m. the flame speed will be only some 30 times the *average* piston speed. In other words, the flame rate has doubled compared with an increase in piston speed five times as great.
>
> A simple consideration like the above leads to the inevitable conclusion that other factors than simple adiabatic heating must enter into the regulation of combustion in engine practice.

In the foregoing Whatmough infers by deduction that the flame speed must be much greater relative to the piston speed at lower engine-speeds than at higher

engine-speeds, and this difference in flame speed must be provided for by increased warming of the mixture at low speeds, to speed up the flame.

Turbulence Varies with Speed

We believe that Whatmough has entirely overlooked the effect of the difference in turbulence created by differences in engine speeds, which serves to speed up the flame and acts to balance the flame time between speeds. Ricardo has ably demonstrated this fact, and his data on this point are to be found in our Ricardo review. I believe that this brings out a fault of purely physico-chemical deduction, which is that it may bring about a tendency to overlook the ordinary. Another instance of this is incorporated in the following paragraphs from Whatmough's communication to me:

> It is well known that the temperatures and pressures observed in petrol engines are considered below theoretical possibilities. Evidence collected by me during the course of the last two years proves that the available pressure rise is definitely limited by combustion being in a "state of suspense" due to the attainment of physico-chemical equilibrium.
>
> For example, a heavy-duty engine of 5-in. bore developed 40 hp. at 700 r.p.m. with a combustion-head giving 4:1 compression ratio and a compression pressure of 88 lb. per sq. in. The same engine with streamlined combustion-head giving 5.5:1 compression ratio and a compression pressure of 117 lb. per sq. in. gave an increase of some 6 per cent in power as compared with the anticipated 30 per cent, the latter being realized, however, at speeds above 1500 r.p.m.
>
> It is facts such as these that cannot be explained by the older thermodynamics, but are easily understandable upon physico-chemical principles.

[21] Unpublished data.

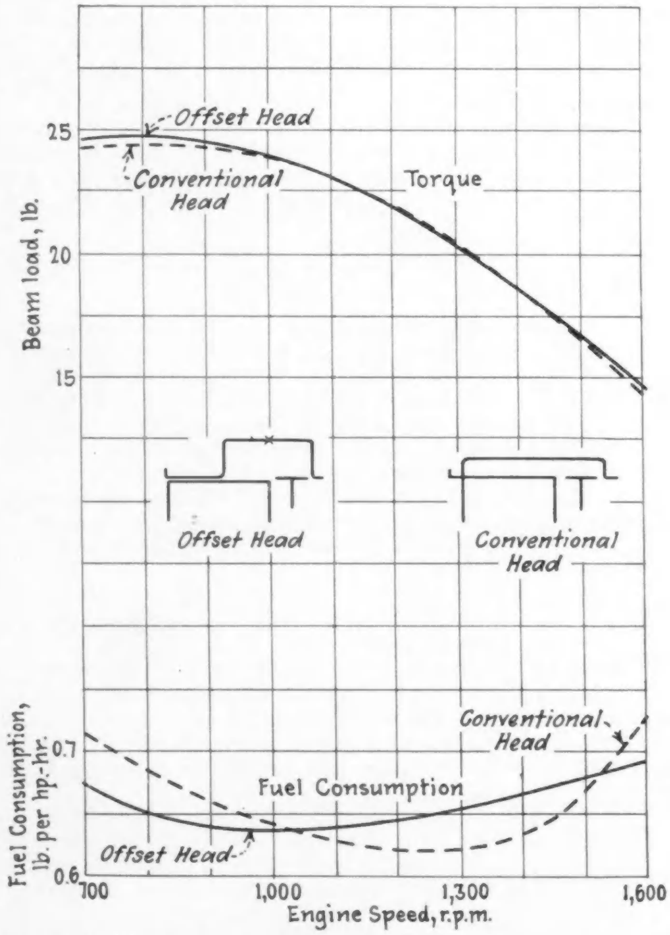


FIG. 23—COMPARATIVE EFFICIENCY OF CONVENTIONAL AND OFFSET HEADS

Piston-Ring Seal Sets a Limit

Failure of power improvement at low speeds, with increased compression and pressures, is not unusual. We have always been able, however, to locate the fault in piston-ring seal, which is critical. The seal may be good under certain circumstances but just a little more load on the rings may cause the seal to go from good to bad.

We believe this simple answer is typical of the type of solution that is likely to be overlooked by the physical chemist who may not give sufficient consideration to the practical.

Undoubtedly, great progress-making truths will be brought to light by the physical chemist, and we are sure that Whatmough will not be among the laggards in this work. He most certainly has the courage of his convictions, and we hope that he will record his progress in a manner that will permit us to follow; for our willingness is high, although our comprehension may be low.

I believe that I have shown that there is very little difference in practice between Ricardo and Whatmough with the exception of Whatmough's streamlining around the valves and Ricardo's rate of change in section area of the main chamber before entering the clearance space. The great difference in the statements made by the two investigators is unfortunate.

PART 3—JANEWAY'S CONTRIBUTION APPRAISED

I am probably in a better position to review the work of Janeway than that of Ricardo or Whatmough, having had many personal discussions with him in addition to direct associations during his investigations at the laboratories of the General Motors Corp.

Janeway began his investigation on combustion-chambers in the early part of 1923. Previous to that, he was associated with Midgley in his combustion investigations with various fuels. He differs greatly from either Ricardo or Whatmough. He is not the all-round designer that Ricardo is nor the chemist that Whatmough is; he is fundamentally the mathematician, with an extraordinarily broad understanding of thermodynamics. A heat unit to Janeway is as definite as a piece of steel.

Janeway is a rapid, tireless investigator and a deep prober, impatient with us who lag behind. It is because of his ability to delve deeply that he becomes disrespectful when he suspects superficiality. He has freely admitted that he owes a great deal of his inspiration to Ricardo, although he criticizes Ricardo for not seeking deeper into his problems.

In 1924, Janeway was engaged in determining the merits or demerits of the high-turbulent Ricardo head. He determined[21] from these investigations that:

(1) Regardless of form, the best firing position for power and detonation is at the center of mass

(2) Combustion-chamber form has very little influ-

ence on thermal efficiency for any given compression-ratio

(3) The offset type of head for L-head engines offers the best possibilities of increasing efficiency through higher allowable compression-ratio for no detonation. However, the compactness inherent in the extreme offset chamber tends to produce a harshness.

With reference to item (1). This is in direct agreement with Ricardo and, like Ricardo, we shall see that Janeway modifies his opinion in the interests of smoothness.

Janeway is evidently arguing in item (2) against Ricardo's claim for greater efficiency due to turbulence. Results of experiments with an offset head and conventional head that he carried on to support item (2) are charted in Fig. 23. Janeway concludes from these data that there is virtually no difference in thermal efficiency between heads of these widely different types at the same compression-ratio.

He offers Fig. 24 in further support of this claim. This is a series of mixture fish-hooks based upon load and air:fuel ratio and upon specific fuel consumption and air:fuel ratio. These curves were made from data secured on a single-cylinder engine, hence we must assume that distribution is not involved in them. The virtual agreement of these curves at the points of maximum economy and the leanest for maximum power support the contention that thermal efficiency is not affected by chamber form for a given compression-ratio.

Our own experience with this method of checking the sensitivity of head shape to mixture ratio agrees with Janeway's findings in a broad sense. However, our work was carried out on a six-cylinder engine using six widely different heads. We found that the maximum-economy point for all heads agreed exactly, but the leanest mixture for maximum power varied appreciably.

I believed with Ricardo that a portion of the wet fuel could become lost in chambers of some types; however, I have modified my stand on this and now believe that this condition applies only to very light loads and extremely high speeds. Particularly is this true in idling when we find it necessary to use large spark-plug gaps to assure idle running. Under this condition, induction turbulence is so low as to fail to mix the exhaust diluent, which is relatively large, with the new charge, which is small, resulting in a stagnation of the exhaust gas around the plug.

Comparing Heads for Thermal Efficiency

However, Ricardo had claimed greater efficiency for the turbulent than with the conventional head, so full-load experiments were sufficient for Janeway; according to whom, if agitation or the lack of it could be effective on thermal efficiency, its effect should show up between a wet and a dry mixture in heads of the two types. Table 2[21] indicates Janeway's results by test under these conditions, showing that with a 13:1 mixture at 237 deg. fahr., which should be dry, the indicated horsepower is virtually the same for both heads. However, the conventional head detonated. The indicated horsepower was practically the same for both heads with a 12:1 mixture at approximately 95 deg. fahr. High-test gasoline was used for the dry mixture, and ordinary Red Crown was used for the wet mixture.

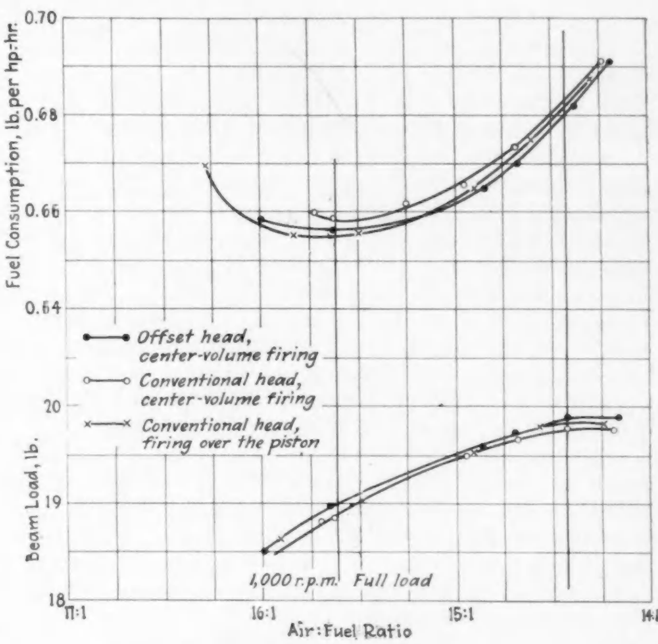


FIG. 24—FUEL CURVES WITH DIFFERENT HEADS AND SPARK-PLUG LOCATIONS

We have noticed that Janeway persistently refers to Ricardo's combustion head as an offset head, rather than a turbulent head. The reason he has given for this is that he is of the opinion that this head is no more turbulent than any other type, since the major creation of turbulence is during induction, and that there is very little additional effective turbulence during the compression stroke when the throat of the chamber is sufficient to permit adequate volumetric efficiency, at least for any modern combustion-chamber.

With reference to item (3) Janeway states[21] that: "The offset head offers the best possibility of increasing efficiency, due to its higher allowable compression-ratio for no detonation." This, Janeway believes, is entirely due to the *clearance space*.

To substantiate his belief in the effectiveness of the clearance space, in 1926 Janeway made some comparative tests on eight different cylinder-heads of the same compression-ratio but with varying thicknesses of clearance space, from 1/32 to ¼ in. The results of these were published[22] in 1928 and 1929.

Ricardo made similar tests, the results of which are reproduced in Fig. 6, herewith. I think that Ricardo's data are more to the point than are those published by Janeway, since Ricardo gave results in the effect on the useful compression-ratio, while Janeway deals in relative border-line spark-advance and the power loss by retarding the spark to the border line.

TABLE 2—EFFECT OF OFFSET HEAD ON THERMAL EFFICIENCY

	Dry Mixture, 237 Deg. Fahr.		Wet Mixture, 95 Deg. Fahr.	
	Offset	Conventional	Offset	Conventional
Indicated Horsepower, Corrected	3.65	3.59	4.47	4.41
Fuel, lb. per hp-hr.	0.700	0.700	0.757	0.728
Spark Advance, deg.	10	15	13	19
Air:Gas Ratio	13:1	13.05:1	11.78:1	12.05:1

[21] Unpublished data.

[22] See *Automotive Industries*, Nov. 3, 1928, p. 622; Nov. 10, 1928, p. 662; also S.A.E. JOURNAL, May, 1929, p. 498 and TRANSACTIONS, Vol. 24, 1929, p. 139.

Fig. 25 indicates the percentage of power loss for border-line detonation. Analysis of these data indicates a loss of about 1 per cent with 1/32-in, clearance, and 1¾ per cent with 1/16-in. Obviously, 1/32 in. is impractical, but 1/16 in. is about the general practice, it being convenient to use since it is the equivalent of the thickness of one gasket. In Fig. 6 Ricardo indicated that there is virtually no relative advantage between 1/32-in. and 0.085-in. clearance space in useful compression-ratio. Both investigators indicate that the loss is fairly rapid from this point on. The agreement of these data is interesting in view of the fact that Ricardo believes this indicates an extremely critical condition, while Janeway believes that these data indicate no critical condition, because there is only 1¼ per cent loss between 1/32-in. and ⅛-in. clearance.

This gives a fair idea of why confusion exists in regard to combustion-chambers. Yet in considering this point, as stated previously in reviewing Ricardo, practice must determine what is critical and what is not and, since 0.045 to 0.070 is about the general practice and the critical point is above this thickness, I believe that this is not critical.

Area of Shallow Clearance Space

In a further effort to develop the fundamentals of the clearance space, Janeway ran a series of tests on nine cylinder-heads, wherein the plan area of the shallow clearance space was varied to cover from 0 to 40 per cent of the piston. He states that the highest useful compression-ratio for heads having clearance spaces covering from 5 to 40 per cent was 4.8:1. The compression ratio for the head with no shallow clearance space was 4.38:1.

Fig. 26 is a curve showing the percentage of power lost by retarding the spark to border-line detonation. Janeway states[23] with reference to this curve:

> As the extent of the clearance space was increased up to 20 per cent piston coverage, detonation was somewhat reduced, but further increase in clearance space resulted in a slight tendency to increase detonation.

It is interesting to note that, without the shallow clearance space, a loss by spark retard was necessary

[23] See *Automotive Industries*, Nov. 3, 1928, p. 622.

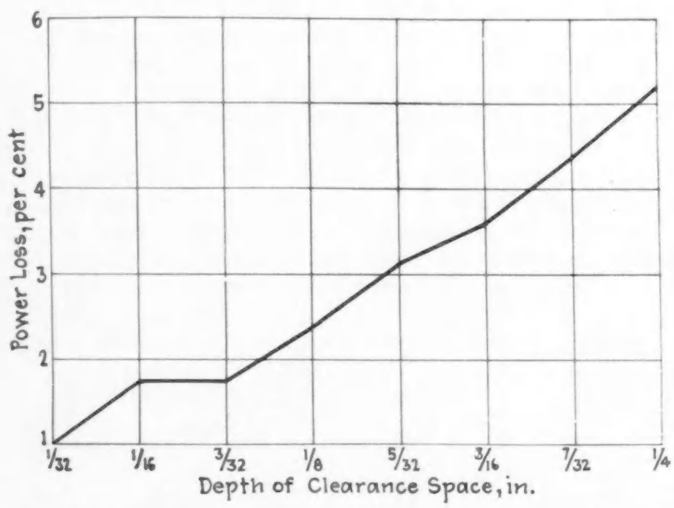


FIG. 25—POWER LOSS FOR NO DETONATION FROM VARYING DEPTH OF CLOSE CLEARANCE

to eliminate detonation in spite of the lowered compression-ratio of 4.38:1.

The fact that a slight tendency to *increase* detonation with an increase in extension of the clearance space beyond 20 per cent can probably be explained by the fact that the effect of the extended clearance space aiding cooling is offset by the fact that the space approaches the center of the piston, which is hotter than the portion more remote from the center.

It is obvious from the data offered in Figs. 25 and 26 that Janeway has established the shallow clearance space and its place in combustion-chamber progress, and therefore he must be considered an early pro-

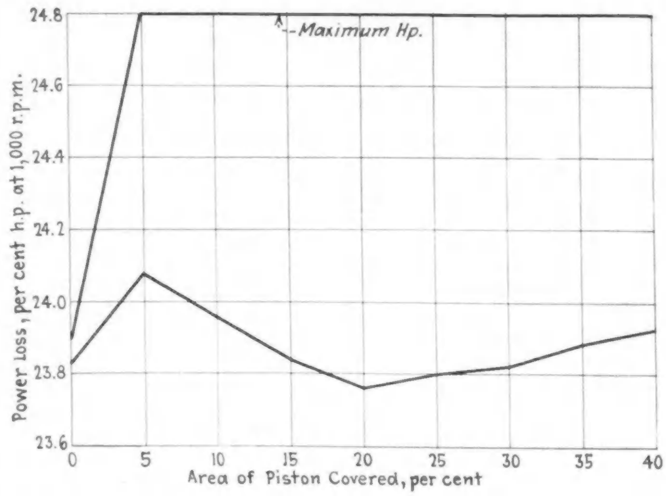


FIG. 26—POWER LOSS FOR NO DETONATION FROM VARYING THE AREA OF THE CLOSE CLEARANCE

ponent, particularly since his work was carried on in 1926.

In 1928, Janeway summarized[23] his combustion-chamber beliefs as follows:

(1) That the effect of the combustion-chamber on detonation is almost entirely due to heat transfer affecting the temperature of the part of the charge which burns last and is determined by the following factors: (*a*) location of that portion of the gas which burns last; (*b*) shape of chamber; and (*c*) location of spark-plug

(2) That while turbulence is an important factor in engine operation, according to experiments, the combustion-chamber form does not appreciably influence the effective turbulence, within limits

Item (1) is in agreement with Ricardo and Whatmough, particularly with reference to (*a*). All three are agreed that it must be in the coolest place, the clearance space, except that Whatmough believes this may be too cool and may require heating. However, even Whatmough has agreed by his practice that the clearance space is where the last gas shall burn.

The shape of the chamber, referred to in (*b*), is claimed to affect detonation. However, each man has his own series of shapes, each maintaining that his general shape is the best. The obvious answer is that the shape is not important; that a wide difference in shape is permissible for the same degree of heat transfer.

With reference to (*c*), location of the spark-plug. Whatmough has definitely adopted a location beyond

the exhaust valve for initial warming and prevention of detonation. Ricardo has maintained that the center of volume is the correct place, and we have seen that Janeway has agreed with Ricardo as to this.

Janeway has stated[21] that: "Regardless of form, the best firing position for power and detonation is at the center of mass." However, he has modified his attitude and his latest heads indicate the spark-plug location as being on the valve center-line, much closer to the exhaust valve than to the inlet.

Agreement on Spark-Plug Location

This modification of spark-plug location has been brought about by investigations on smoothness, and in the face of this necessity both Ricardo and Janeway state in effect that the loss in detonation for this position as against center-of-volume position of the plug is negligible.

With Whatmough and Janeway using the exhaust-valve locale for the spark-plug and Ricardo doing likewise in his "shock-absorber" head, originally contrary opinions are washed out.

With the spark-plug position fairly well settled, we shall return to Janeway's record of nine combustion-chambers. These chambers are alike except for the extension of the clearance space. This variation served to produce heads with varying degrees of offset, and the data on power output between these heads are as shown in Fig. 26. The power is constant at 24.8 hp. for the eight offset heads, and is only low where the compression ratio has been lowered from 4.8 to 4.38 for the head without shallow clearance space.

Janeway's remarks[24] on this are as follows:

> These results are of additional significance in that, although the communicating area between chamber and cylinder was considerably changed in this series of heads, there was no evidence of any effect on turbulence. Detonation tendency did not follow decrease in communicating area, nor was there any reduction in required spark advance between 5 per cent and 40 per cent piston coverage to indicate speeding up of combustion. It appears, then, that combustion-chamber form, within considerable limits, has no influence on the effective turbulence.

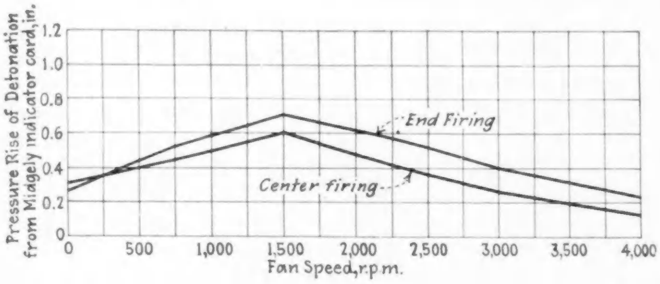


FIG. 27—CHANGE IN DETONATION WITH DEGREE OF TURBULENCE

Thus Janeway establishes the fact that chamber shape, within wide limits, has no influence on turbulence, and the difference between an anti-turbulent and high-turbulent head is washed out. Whatmough states that turbulence heats the mixture. Ricardo infers that it cools the mixture; both agreed more or less that it increased the rate of burning, and therefore the efficiency.

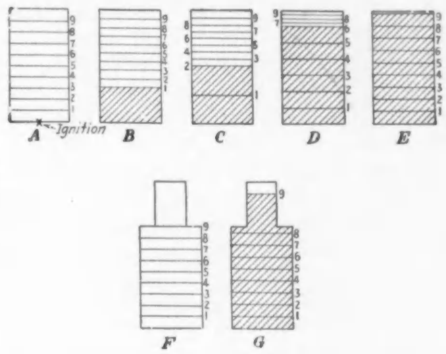


FIG. 28 — COMPRESSION OF UNBURNED GAS DURING COMBUSTION

Diagrams *A-E* Show Successive Stages of Equal Quantities of Gas in a Plain Bomb. *F* and *G* Represent a Modified Bomb Illustrating the Effect of Narrow Clearance Space

Janeway offers evidence to the effect that turbulence is a constant over a wide range of shapes. However, he believes that turbulence is a factor in detonation, and in support of this has offered the illustration[25] shown in Fig. 27.

These data are a record of bomb experiments wherein a bomb was made, the characteristics of which, as far as explosion time was concerned, agreed substantially with that of an engine under observation. This agreement was obtained by inserting a variable-speed fan within the bomb and changing the speed, and therefore the turbulence, to obtain the correct time. Detonation was recorded by a Midgley indicator.

It is seen from Fig. 27 that detonation is at its height at 1500 r.p.m. of the fan. At lower fan-speeds, or lower turbulence, we find that detonation is lower, probably because the flame speed is so slow as to permit cooling of the unburned gas below the critical temperature. The fact that detonation decreases as the fan speed, or turbulence, increases is no doubt due to the scrubbing of the unburned gases on the surface, thus transferring heat by convection and lowering the temperature of the unburned gas below the critical.

From the review of Janeway, so far, it is obvious that he is a splendid investigator, and that the superficial has no place in his activities. His thorough research on the clearance space, constancy of thermal efficiency, and the true nature of turbulence are as convincing as they are conclusive.

Compressing Effect of the Combustion

Janeway's famous diagram, which is usually found wherever Janeway has published any combustion data, is reproduced in Fig. 28. It is an exposition of the super-compression of the unburned gas during combustion[26]. It is similar to a diagram that was originally published in 1923 by Midgley and Janeway[27]. Janeway's use of it was inspired by Ricardo's explanation of the heating of the unburned gas by compression due to rapidity of the pressure rise of the burning gas.

It must be remembered that Ricardo sought to control this undesirable effect by shortening the flame travel. He stated in this respect that the shortest possible flame travel was the element in his "turbulent" head that was responsible for the low detonation characteristics. Thus we see that, while Ricardo originally

[21] Unpublished Data.

[24] See *Automotive Industries*, Nov. 10, 1928, p. 664; S.A.E. JOURNAL, May, 1929, p. 504; TRANSACTIONS, Vol. 24, 1929, p. 145.

[25] See *Automotive Industries*, Nov. 3, 1928, p. 623.

[26] See S.A.E. JOURNAL, May, 1929, p. 501; TRANSACTIONS, Vol. 24, 1929, p. 142.

[27] See THE JOURNAL, April, 1923, p. 367; TRANSACTIONS, Vol. 18, 1923, p. 51.

pointed the way for Janeway and his associates, he himself at that time was not ready to follow.

Fig. 28, from *A* to *E*, represents a combustion-chamber divided into ten volumes. At *A* they are equal. The diagram illustrates how each volume successively expands as it burns and compresses both the burned and the unburned charge until, at *E*, the last volume to burn is shown tremendously compressed. *F* and *G*, in Fig. 28, show an extended section which is presumed to represent the clearance space. The increase in surface:volume ratio is obvious, and the improvement in cooling of the last portion in *G* is likewise understandable.

Janeway points out that convection plays an important part in cooling, and that the gas movement in the last portion to burn is much greater in *G* than in *E*.

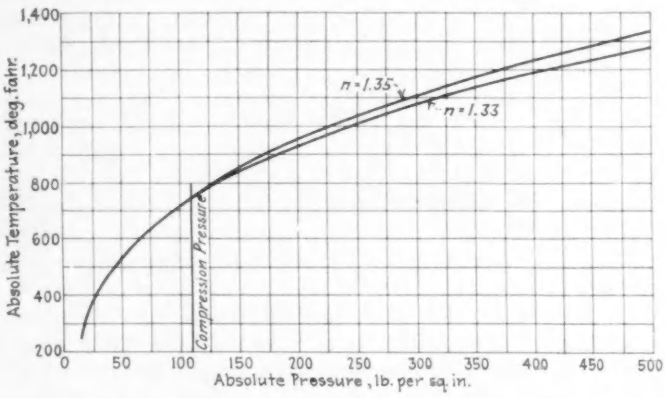


FIG. 29—RELATION BETWEEN TEMPERATURE AND PRESSURE OF UNBURNED GAS

In my discussion of the heating or cooling effect of turbulence I referred to the temperature of the charge at ignition and also to the probable temperature of the last gas to burn.

Temperature Rise of Unburned Charge

Janeway has published[28] a curve of the unburned charge temperature throughout the burn. This is shown in Fig. 29. The temperatures given are in degrees fahrenheit absolute.

It is seen that the self-ignition point of the fuel is passed before the critical temperature is reached. This autoignition temperature is approximately 1300 deg. fahr. abs. or 850 deg. fahr. Yet operation is normal above these temperatures. The reason given by Janeway for this is the time lag of autoignition which is relatively great in comparison with regular inflammation. This fact apparently throws a cloud around the theory that detonation is a form of autoignition. The explanation may be, however, in the fact that the lag is materially reduced by temperature until no lag exists, at which time instantaneous autoignition occurs.

Janeway indicates an initial temperature of the mixture before compression as 700 deg. fahr. abs. Let us check this with the 5:1 ratio, assuming the normal temperature of the mixture to be 150 deg. fahr. and including the heat absorbed from the metal. Then we must consider the exhaust diluent, which for 5:1 is 25 per cent by volume or 12 per cent by weight. The temperature of this exhaust gas can be assumed as the equivalent exhaust-port gas-temperature, which, on a fair engine, will be 1200 deg. fahr.

Then, with 1200 deg. fahr. as the exhaust residue, 12 per cent as the weight of the residue and 150 deg. as the fuel-air-mixture temperature:

$$(1200 - y) \times 0.12 = y - 150$$
$$y = 260$$

Therefore the initial temperature = 260 + 460, or 720 deg. fahr. abs.

This gives us about 1050 deg. fahr. abs. for 5:1 compression, which means about 600 deg. fahr. for the mixture temperature at ignition.

With this as the initial temperature, Whatmough's turbulent heating certainly falls by the wayside, since it is obvious that at no time can heat flow to the mixture except during induction and locally from the exhaust valve.

End Wall of Combustion-Chamber

We now come to the design of the wall adjacent to the clearance space, and Fig. 30 is an illustration that Janeway has used[29] to demonstrate his theories. The offset chamber at the left has a straight wall. Janeway argues pictorially that the last gas to burn, which is being super-compressed into the clearance space in the process, will be brought into impact with the wall. The resultant scrubbing action, he maintains, is beneficial in its tendency to remove heat from the unburned mixture. The center view in Fig. 30 is of a Ricardo "turbulent" head. Janeway indicates that a curved end-wall will tend to direct the mixture inwardly against itself, thus interfering with the scrubbing effect, and he infers that the temperature of the last gas to burn will be higher with this form. At the right is a fairly standard type of head that does not incorporate a vertical end-wall, and in this particular represents Whatmough's "streamline anti-turbulent" head. Janeway indicates a relatively gentle easing of the last gas into the clearance space with the minimum of scrubbing action, hence it will enter the clearance space with a higher relative temperature than would be the case with the vertical-wall design.

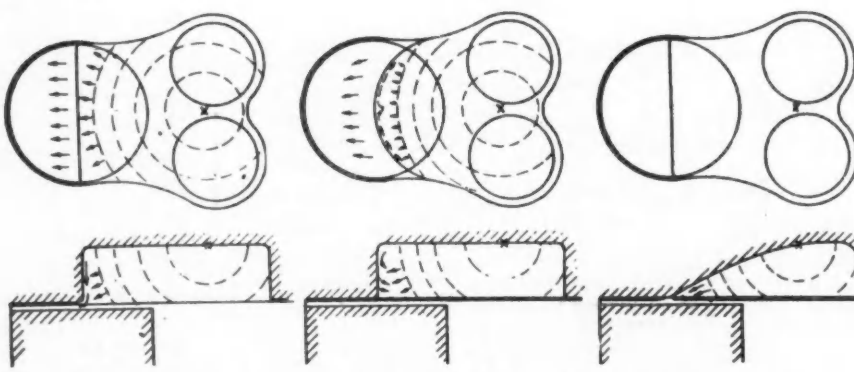


FIG. 30—EFFECT OF END-WALL SHAPE ON FLOW OF UNBURNED GAS

[28] See *Automotive Industries*, Nov. 3, 1928, p. 623; S.A.E. JOURNAL, May, 1929, p. 501; TRANSACTONS, Vol. 24, 1929, p. 142.

[29] See *Automotive Industries*, Nov. 10, 1928, p. 664.

[30] See *Automotive Industries*, Nov. 10, 1928, p. 665.

Fig. 31 indicates the results of a test made to determine the value of this wall[30]. The upper curve is a maximum-torque curve of two cylinder-heads of the same compression-ratio. One head incorporated a straight vertical end-wall and the other was streamlined. The upper jagged line represents the torque for the head with the vertical end-wall, at no detonation. The lower curve represents the torque of the streamline head at no detonation. In each case the spark was retarded to the border line of detonation. These data indicate an advantage for the vertical wall. However, I am sure that the same advantage could not be shown for the straight vertical end-wall in comparison with the curved vertical end-wall. I believe from my own experience that a vertical end-wall is necessary and that the higher it is the better it is for cooling; however, its shape must depend upon what may be necessary for smoothness.

This delving into the helpful properties of the vertical end-wall is additional evidence of the ability of Janeway to probe and search for facts, which virtue is serving to make this man's work of extreme value to the industry.

Janeway recommends that the compact chamber be replaced by a much more extended chamber. Examination of Ricardo's "shock-absorber" chamber and Whatmough's "anti-turbulent" chamber discloses the fact that the major difference between these chambers and Ricardo's original offset chamber is in the degree of compactness. The two "smooth" heads are not compact. Janeway's anti-shock chamber, as in use today and shown in Fig. 32, is also definitely non-compact. This, therefore, is a common factor for Whatmough, Ricardo and Janeway.

Janeway has published some very fine data with reference to the mathematical control of the volume burned[31], which makes possible a predetermination of the degree of roughness. Ricardo has accepted pressure per degree of crank angle for the maximum rate of pressure rise as the controlling element for smoothness or roughness. However, he has stated that it is possible to have a very high maximum rate per degree

[31] See S.A.E. JOURNAL, May, 1929, p. 512; TRANSACTIONS, Vol. 24, 1929, p. 153.

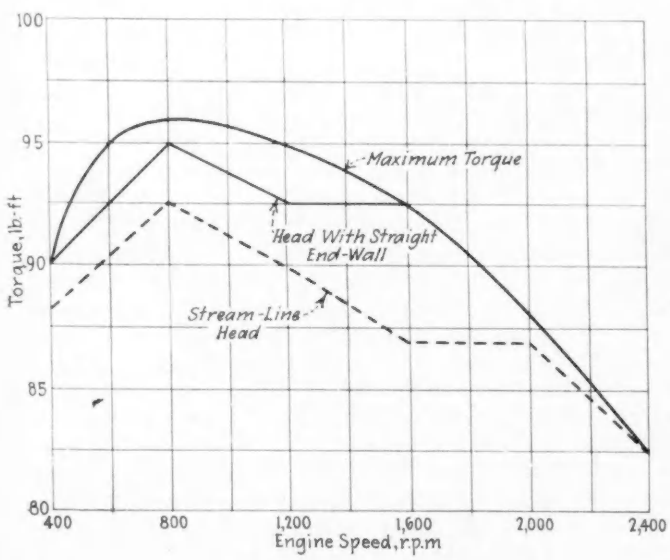


FIG. 31—EFFECT OF END-WALL SHAPE ON DETONATION

with smooth results provided the initial burning is extended.

Janeway maintains that the rate of change or acceleration of the pressure rate is the controlling element. This means that a sudden change in rate will indicate roughness.

Examination of Ricardo's and Whatmough's indicator cards brings out the fact that the cards for smooth results show a gradual change of rate, and that cards for a rough engine indicate a rapid change in rate. Thus we can establish still another common factor to which Janeway, the mathematician, points.

Characteristics Charted for Comparison

Figs. 33, 34 and 35 are pressure-rise analyses of indicator cards of Ricardo, Whatmough and Janeway, worked out to a common scale to make possible a direct comparison of the acceleration. Fig. 33 is replotted from Fig. 6, in which Ricardo shows indicator cards representing a rough and a smooth condition. I have followed these curves as carefully as possible. The new curves are of the rate of pressure rise per degree of crank angle for each position throughout combustion. Thus the acceleration is readily comprehended, and the true nature of the relative roughness is quickly observed.

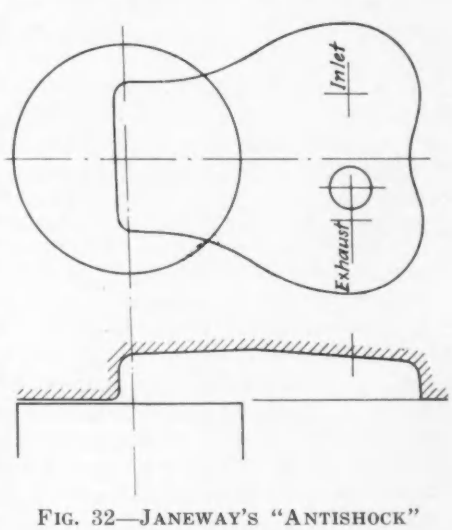


FIG. 32—JANEWAY'S "ANTISHOCK" HEAD

The smooth curve indicates a maximum rate of pressure rise of 28 lb. per deg. and a maximum acceleration of 4.8 lb. per sq. in. per deg. per deg. The rough curve indicates a maximum rate of pressure rise of 34 lb. per deg. and a maximum acceleration of 13 lb. per sq. in. per deg. per deg. The ratio of values for maximum rate of pressure rise is 1.21:1, whereas the ratio of acceleration values is 2.70:1. Obviously, the 21-per cent increase in maximum rate is not comparable with the acceleration increase of 170 per cent.

Fig. 34 is replotted from Whatmough's combustion curves in Fig. 15, which represent a normal and a smoothed curve. There is a tremendous difference between the Ricardo and Whatmough results. The application of the common scale and factor bring out that their smoothness ideals do not agree. This is accounted for by their evident lack of a proper yardstick.

We see here that Whatmough's normal curve is smoother than Ricardo's smooth curve, and that his smooth curve based on acceleration is dead smooth, 0.80 lb. per sq. in. per deg. per deg. The acceleration of his normal, or presumably rough, curve is 2.57 lb. per deg. per deg. Whatmough does not explain in these data whether these are actual or theoretical indicator cards, but the difference in result might be accounted for by the degree of compactness of the two

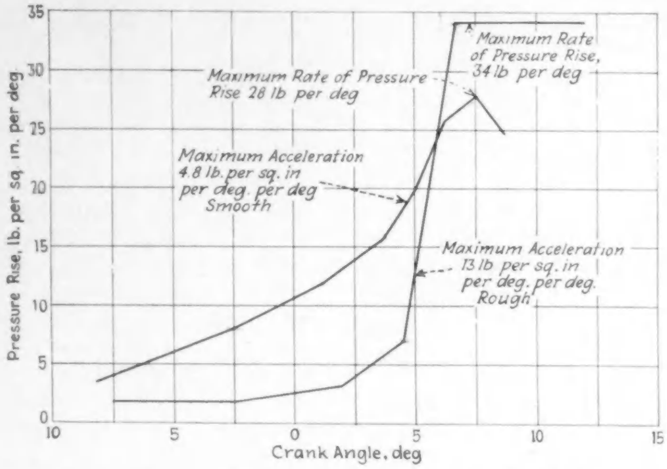


FIG. 33—PRESSURE-RISE ANALYSIS OF RICARDO'S CURVES IN FIG. 6

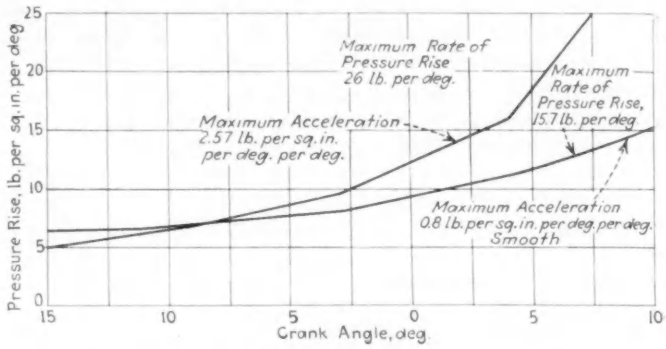


FIG. 34 — PRESSURE-RISE ANALYSIS OF WHATMOUGH'S CURVES IN FIG. 15

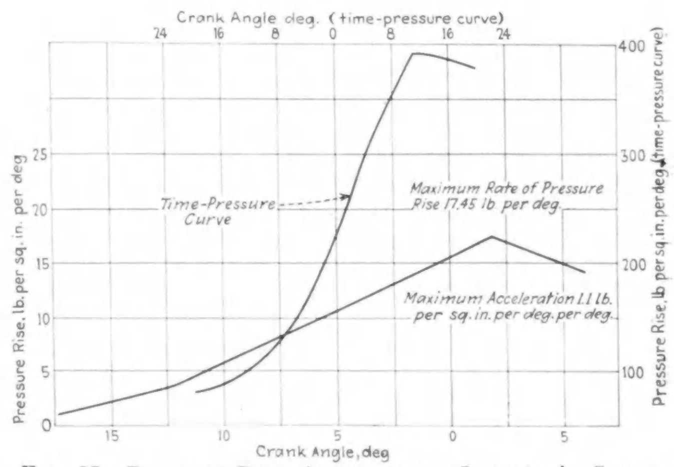


FIG. 35—PRESSURE-RISE ANALYSIS OF JANEWAY'S SMOOTH ENGINE

designs, Whatmough's chamber being much less compact.

Fig. 35 shows Janeway's curves of a smooth engine. These data are comparable with the Whatmough ideal and serve to substantiate the thought we obtain by the Ricardo and Whatmough comparison, which is that Ricardo can go much further in smoothness than his data indicate.

Procedure for Roughness Control

We will now examine the Janeway procedure for roughness control. Whatmough, it must be remembered, uses "directional firing" from a warm zone into increasingly cooler zones as a means of roughness control. That this must take into consideration a surface:volume-ratio increase is obvious. However, he has never revealed his method of proportioning or determining correct proportion of how the surface:volume ratio must vary. The probability is that this information does not exist.

Ricardo, it should be remembered, claims roughness control by turbulence control. Janeway has shown us that turbulence does not vary over a wide difference in combustion-chamber form. However, we cannot reject the work on smoothness by Whatmough or Ricardo, since there is evidence in their publications that relatively smooth results have been obtained.

Janeway controls roughness by regulating the volume progressively burned. This is accomplished by control of the flame-front area, which is equal at all times to the area of unburned gas that is exposed to inflammation. He has gone further in his exposition of shock than either Ricardo or Whatmough; he has published a means of evaluating shock or roughness and indicator cards[32] representing smooth and rough results.

Janeway presented[32] a method of graphically determining shock. This system may be a delight to the engineer or physicist who is mathematically inclined, but it is far from being a delight to me, particularly from the standpoint of "popularizing." Briefly, this system recognizes that shock is a matter of deflection of the structure, and that must depend upon the acceleration of the force actuating it. When actual time and loads are considered, these forces assume tremendous values and impart to the structure stored forces that must be restored to regain equilibrium. The effects of these values are much higher than the possible effects of the static loads resulting from the maximum pressure.

Table 3 indicates[33] the tremendous values that must be considered when time and pressure are combined. Janeway refers to these data as a "quantitative comparison of smooth and rough engines." From this table we see why the acceleration is the more important

[32] See S.A.E. JOURNAL, May, 1929, p. 509; TRANSACTIONS, Vol. 24, 1929, p. 150.

[33] See S.A.E. JOURNAL, May, 1929, p. 510; TRANSACTIONS, Vol. 24, 1929, p. 151.

TABLE 3—QUANTITATIVE COMPARISON OF SMOOTH AND ROUGH ENGINE

	Smooth	Rough	Relative
Maximum Rate of Pressure Rise, lb. per sq. in. per sec.	162,300	344,000	2.18
Restoring Force, lb. per sq. in. per sec.	188,370	465,000	2.47
Maximum Acceleration in Pressure Rise, lb. per sq. in. per sec. per sec.	93,000,000	567,000,000	6.1
Restoring Force, lb. per sq. in. per sec. per sec.	149,000,000	605,000,000	4.05
Relative Kinetic Energy of Deflecting Mass, $(2.47)^2$			6.10
Maximum Restoring Force, lb. per sq. in.	439	543.7	
Maximum Pressure, lb. per sq. in.	410	410	
Shock Factor, per cent	7.07	32.6	4.6

Note—The shock factor is obtained by the formula
$$\frac{\text{Maximum Restoring Force} - \text{Maximum Pressure}}{\text{Maximum Pressure}}$$

item. The maximum rate of pressure rise in pounds per square inch per second is 2.18 times as much for the rough engine as for the smooth. The ratio of difference, however, for maximum acceleration in rise per pound per square inch per second per second is 6.1 times as much for the rough as for the smooth.

Janeway states that neither of these figures is the absolute value of the difference in shock, since the ratio between the rough and the smooth head for his actual shock factor is 4.6. He suggests that the averaging of the ratio difference of the heads between maximum rate and maximum acceleration comes very close, being 4.14. However, he advises against an empirical method and states that for fundamental comparison the work should be carried through.

Acceleration in Pressure Rise Measures Roughness

Obviously, for ordinary comparative results a direct comparison of the acceleration of the pressure rise should be sufficient to guide the engineer as to whether or not he may expect an improved result. This is undoubtedly a splendid piece of applied mathematics. With time and a better understanding, we are sure that this work will be so recognized.

I am convinced that Janeway's determination that acceleration of the rate of pressure rise is the factor that we must deal with for roughness control offers us the common yardstick for combustion-smoothness measurement. This principle squares up Ricardo, who became inconsistent with the development of his "shock-absorber" head. We must remember that he had established pressure per degree of crank angle for the maximum rate as the important factor. He had stated definitely that 35 lb. per deg. of crank angle should not be exceeded for smoothness. With the advent of his antishock work he finds that smoothness can be had with a maximum pressure rate far in excess of his original recommendation. He has explained it by the camshaft analogy; however, what he has actually done is to reduce the acceleration considerably, reducing the rate of change rather than rate of the pressure rise itself.

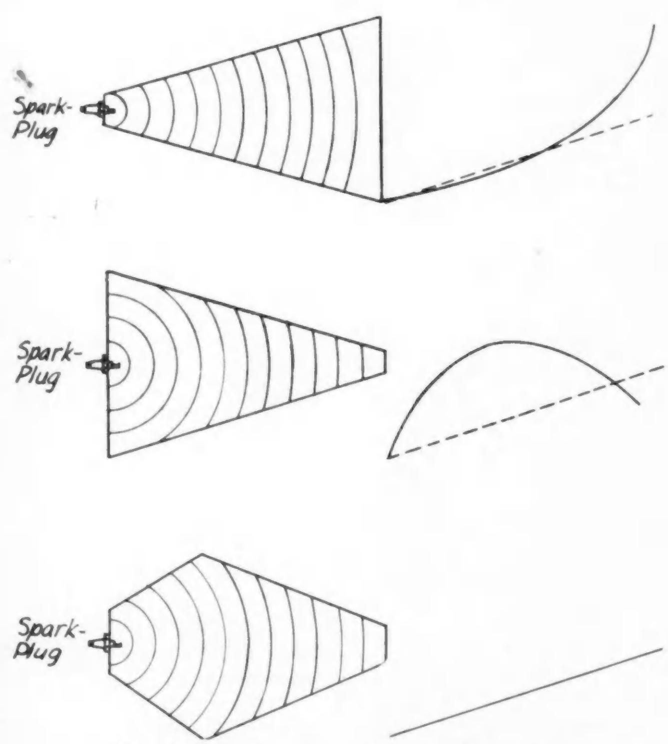


FIG. 36—A STUDY OF CONICAL CHAMBERS

The Upper Chart Shows Increasing Acceleration of the Burning; the Center, Decreasing; and the Lower, Approximately Constant. The Straight, Sloping Line in Each Case Represents Constant Acceleration

In the past Whatmough has accepted Ricardo's maximum pressure rate as a basis of comparison; however, the example he has offered incorporates low acceleration values.

Thus the common factor for smoothness becomes acceleration.

Having established this comparative yardstick, we will now examine Janeway's mechanism for controlling acceleration of the pressure rise. Janeway's method is volume control.

Control of Volume Burned

Let us assume a combustion-chamber in the form of a cone. Should the spark-plug be located at the apex, the flame-front area would increase progressively at a rapid rate as inflammation progressed; however, if the spark-plug be located in the base of the cone, the flame front area would be reduced toward the end of the burning. Undoubtedly, firing from the base into the apex would give smoother results; however, the acceleration at the beginning of the burn would be far too rapid for ideal results. Fig. 36 roughly illustrates this principle. I have indicated in the lower diagram how the cone may be modified so that the firing will be from apex to apex, which will tend to result in uniform acceleration throughout the burning.

We have seen how Ricardo controls his initial burning by reducing the volume of mixture exposed to ignition in the vicinity of the plug by reducing the chamber height. The top and bottom walls act as cut-offs. When inflammation progresses beyond this area of control, the volume burned per unit of flame-front travel is increased by the greater depth. The volume burned at the flame front approaching the end of the burning is controlled by the taper appearing in the left plan view in Fig. 37.

Whatmough, by locating his spark-plug adjacent to the chamber wall as shown in the middle view of Fig. 37, obtains a cut-off because of the proximity of the wall. This, combined with the reduction in height due to streamlining at the valves, serves to produce the same general result as does Ricardo, except as it may be affected by the relative compactness. However, the common factor is volume control rather than turbulence or surface:volume control.

From Fig. 37 it can be seen that the intermediate rate of burning for both Ricardo and Whatmough is approximately the same, both being at the maximum.

It is obvious that, with the principle of volume control, it is possible to shape the chamber or locate the plug so as to shift the volume around with respect to the ignition point to obtain almost any desired combustion result, and this is the basis of Janeway's combustion control, the principle of which we have seen can be applied as a common factor to the smoothness work of Ricardo and Whatmough.

Mathematics Applied to Control

However, Janeway, being an investigator with an extraordinary mathematical background, has attempted

to embody in this project a mathematical control that would permit of near-exact predetermination.

With reference to this, Janeway states[34] as follows:

> Having determined the kind of characteristic that is desirable for smoothness, how can we go about building this characteristic into the actual combustion-chamber? The answer to this question also is to be found in the fundamental of flame propagation. As brought out previously, both the burned and the unburned gases are compressed during combustion, the burned gas tending to remain at constant temperature and the compression of the unburned gas being almost adiabatic. On this basis, the relation between the burned-gas volume and the pressure can readily be derived, as shown in detail in Appendix 1.[35]

Janeway has worked out this relationship in the curve which is reproduced as Fig. 38. This curve gives the ratio of pressure to percentage of total gas burned, and assumes that the exponential characteristic for the unburned-gas compression is 1.25 and the ratio of maximum to initial pressure is 4.14:1, which is a representative empirical figure for compression ratio within the commercial range. In order to calculate the volume of the gas burned at any position of the flame front, we must assume that this flame front is relatively uniform. Its tendency to expand in spherical forms is obvious; however, its uniformity must be considered as an assumption. Perhaps it is quite safe to assume this, as whatever variations may exist should not be of such moment as to spoil a comparison. Since physical checks of mathematical differences in smoothness do follow the smoothness trend, at least in my own experience, I feel that this procedure is meritorious.

It is possible then to divide a combustion-chamber into flame-front volumes, and the pressure at each volume burned can be determined by means of the relative pressure chart. It is necessary of course, for comparative purposes, to assume that the piston is at the top of the stroke throughout the burning. This assumption can be corrected for actual volume after the chamber is designed, although such correction is unnecessary for comparison between two or more chambers.

[34] See S.A.E. JOURNAL, May, 1929, p. 510; TRANSACTIONS, Vol. 24, 1929, p. 151.

[35] See S.A.E. JOURNAL, May, 1929, p. 512; TRANSACTIONS, Vol. 24, 1929, p. 153.

[36] See S.A.E. JOURNAL, May, 1929, p. 511; TRANSACTIONS, Vol. 24, 1929, p. 152.

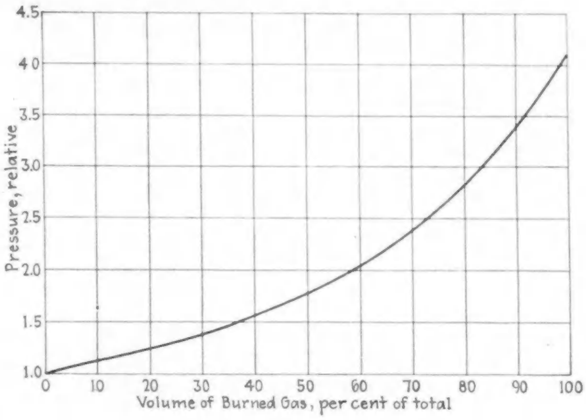


FIG. 38—FUNDAMENTAL RELATIONSHIP BETWEEN PRESSURE AND BURNED-GAS VOLUME DURING COMBUSTION

This establishes the pressure at each point. However, it is now necessary to establish time, and Janeway states[36] with reference to this:

> In the physical chemistry of reactions it is fundamental that reaction velocity, or the weight of reagents burned per unit of contact area in unit time, increase directly with the density of the reagents and as some power of their temperature that is greater than unity. Since the temperature, pressure and density of the unburned gas are interrelated according to the characteristics PV^n = a constant, the variation in reaction velocity and, hence, in flame velocity, can be expressed as a function of some power of the pressure, as derived in detail in Appendix 2.[35]

Janeway follows this with a statement on the temperature rise of the unburned gas:

> The lower the rate of temperature rise of the unburned gas during combustion, the less will be the acceleration in flame velocity. For this reason, the better the cooling provided by the chamber walls upon the unburned gas, the smaller will be the value of the exponent.

This takes into consideration the effect on time of cooling the unburned gas during inflammation and indicates its importance. This portion of the phenomenon of inflammation Whatmough uses as his principle; however, he has never definitely stated a method of using it.

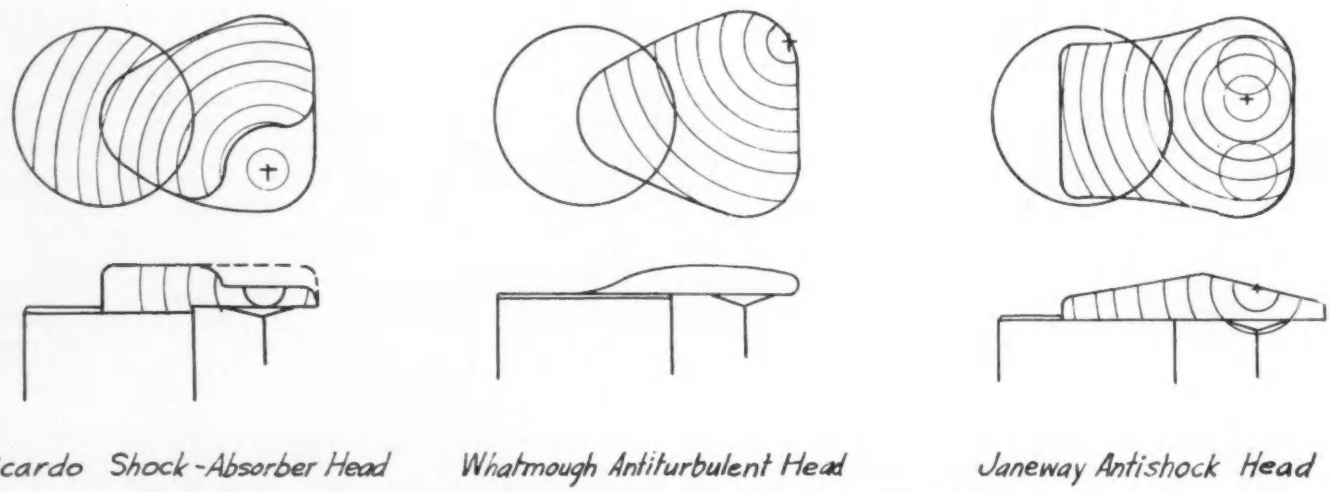


FIG. 37—THREE HEADS DESIGNED FOR SMOOTH COMBUSTION

Janeway obtains time by dividing distance by velocity.

Fig. 39 indicates a graphical method of determining flame travel in relative time by means of a curve of time in percentage of the total. This curve is derived by plotting a curve of the reciprocals of relative flame velocity against linear distance. Relative flame velocity is proportional to some power of the pressure. Janeway points out[36] that the area enclosed below this curve will represent time, and the ratio of the included area for any position of flame front to the total area is the corresponding percentage of the total time.

A theoretical time-pressure curve of combustion, which in turn can be analyzed for acceleration, is obtained by plotting the pressure against the corresponding percentage of the total time. Should the analysis indicate a condition of excess acceleration on account of too much volume at any given place, these calculations will indicate where the volume should be modified. Quite often too great an acceleration is found because of too abrupt a change in section. Corrections can be made in any such case.

Janeway claims that these calculations are characteristic of the truth and offers Fig. 40 in support of his

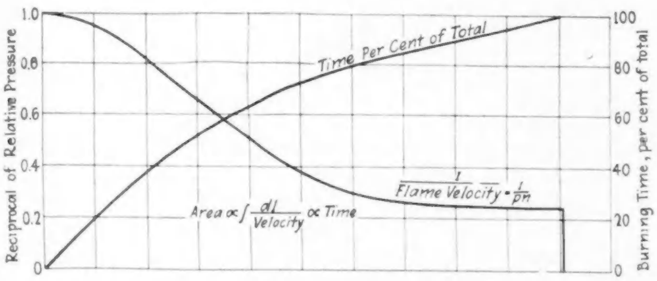


FIG. 39—GRAPHICAL METHOD OF DETERMINING FLAME TRAVEL IN RELATIVE TIME

contention. This figure indicates his calculated combustion curve compared to an actual indicator card of a production engine.

We think that, taken by and large, Janeway's mathematical combustion-chamber progress will be accepted as being one of the finest thermodynamic contributions that has been applied to the internal-combustion engine in recent years. I believe it fitting to remark that Janeway, as an American, refutes the prevalent notion existing in Europe that American automotive work is superficial, and that only in Europe is engineering fundamental.

PART 4—COMMON FACTORS FOUND

The greatest point of satisfaction to me is the fact that through Janeway's work we find the fundamentals underlying the common factors of combustion-chamber design which explain why several workers obtain the same relative result, although their stated methods appear to be different.

The common factors are:

(1) Cooling the last gas to burn by means of a shallow clearance space

(2) Locating the spark-plug at or near the exhaust valve, to make sure that the gas heated by the exhaust valve is not the last to burn

(3) Non-compact combustion-chambers

(4) Volume control for smoothness by

(a) Restricting the initial volume burned

(b) Providing maximum flame spread at intermediate inflammation.

(c) Restricting the flame spread at the end of the burning in the main chamber

(5) Acceleration of the rate of pressure rise is the true measure of roughness.

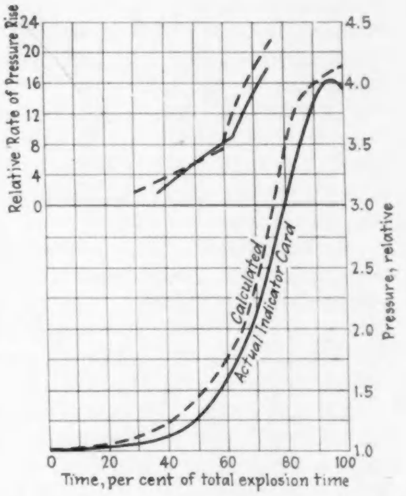


FIG. 40—COMPARISON OF ACTUAL AND COMPUTED PRESSURE-TIME CHARACTERISTICS

We find that these five principles can be applied to the cylinder-heads of Ricardo, Whatmough, and Janeway, and when so applied the results agree proportionately.

Combustion-chamber progress we find has been inspired by Ricardo and carried along by him through patient research. Whatmough has contributed by a modification of English combustion-chamber practice that is decidedly in the right direction, especially in regard to smoothness. Janeway's contribution is in developing the fundamental mathematics and the true thermodynamic values of each of the important elements, and the interrelation of the various elements.

Ricardo and Whatmough by experiment have arrived at designs which embody similar elements. Janeway has determined and definitely evaluated the same elements, thus providing a foundation for rational development.

THE DISCUSSION

CHAIRMAN H. T. WOOLSON[37]:—Mr. Taub has done a wonderful job in trying to condense and straighten out the apparent disagreement among these three writers on combustion-chamber design so that we engineers may be able to utilize their work to the best advantage. It may interest you to know that the reaction of one engineer in our group was such that he sat down and sketched out his own idea of a combustion-chamber immediately after he read the preliminary copy of Mr. Taub's paper.

I am glad that the value of the small clearance space seems to be confirmed from all these sources; we have at least that for a starting point. Mr. Janeway's analysis of smoothness is most interesting; we may well study our indicator cards to see if we cannot profit by this work in finding ways to improve the smoothness of our engines.

[37] M.S.A.E.—Chief engineer, Chrysler Corp., Detroit.

O. C. BERRY[38]:—It seems to me that one more point should be taken into consideration in the design of a combustion-chamber. Mr. Taub has discussed power and smoothness and how to get a satisfactory compromise between the two. He refers entirely to open-throttle operation, while the passenger-car engine is working most of the time at light loads, under which condition fuel economy and positive action are the main considerations.

The modern highly developed automobile engine has a characteristic tendency to be unsteady at idle and light loads. This is true of the best engines, especially those showing the highest brake mean effective pressure. The mechanical efficiency of these engines is very high, and the combustion-chambers are developed to produce such powerful explosions that it is hard to produce regular explosions that are weak enough to do nothing more than keep the engines turning over slowly. The charge in each cylinder is so attenuated and so badly diluted at idle that it is hard to ignite. This condition is at the critical point at idle in engines that show the highest brake mean effective pressure and mechanical efficiency. Our present ignition systems will fire regularly under favorable conditions, but unsteady action and missing will become noticeable if the least thing goes wrong.

All engines will fire a wide range of mixtures under full-load conditions. As the load is lessened and the vacuum in the inlet manifold is increased, the range of mixture ratios that will fire with certainty will also decrease. As the vacuum increases, the dilution due to burned gases increases and the compression decreases, so that after a while a condition is reached in which the engine will fire if the mixture is exactly right, but any variation at all from the correct mixture proportions will lead to trouble. If the intake suction is increased beyond this point, no mixture will fire regularly. The function of the carbureter and manifolding is to supply each cylinder with a correct mixture. If the engine cannot fire a correct mixture with certainty, the carbureting system is helpless. As a matter of fact, some of our engines idle with an intake suction that is so high when the spark is advanced that no mixture will fire perfectly.

Study of Idling Conditions

I have tested an engine on our dynamometer to make this point more definite. The engine was run at 1000 r.p.m. and varying inlet-manifold suctions, and an accurate record was made of how wide a range of mixtures the engine would fire at each degree of suction. The dynamometer equipment included a set of accurate balances arranged to record to 1/5 sec. the time it took to use a pound of fuel. The carbureter was fitted with an adjustable fuel needle, so that the mixture could be varied through a wide range. The engine was run first with an open throttle, and the mixture made so rich that the engine would hunt or miss, and then made leaner until we were barely able to pronounce the operation steady. One pound of fuel was then timed at exactly 1000 r.p.m. The mixture was next made leaner until the engine hunted or missed again and then made richer until the engine was steady, and one pound of fuel was again timed. The air rate of these tests was substantially the same, so that the variation in mixture ratios was the same as the variation in the time required to use 1 lb. of fuel.

Tests like this were run at a number of different inlet-manifold suctions, up to the highest suction at which this engine would idle at 1000 r.p.m. The results of these tests are plotted in Fig. 41, in which the vertical scale represents the inlet-manifold suction, in inches of mercury, and the horizontal scale represents the time required to consume 1 lb. of fuel, expressed in percentage of the average time at that inlet-manifold suction. Mixtures richer than those represented by the left-hand curve or leaner than the right-hand curve would cause missing, but any mixture between these curves fired regularly. This particular engine can fire regularly at 1000 r.p.m. with an inlet suction of 18.5 in. of mercury, provided that the carbureter adjustment is correct. At 18 in. suction, the mixture can be 5 per cent rich or 5 per cent lean without missing, but not more than this. At 19 in., there will be some missing with the best mixture, and the carbureter man can wear his life away to no avail in trying to get a perfect idle.

Engines vary considerably in the intake suction at which they fail to fire regularly. This is an added reason why each engineer should study his own engine

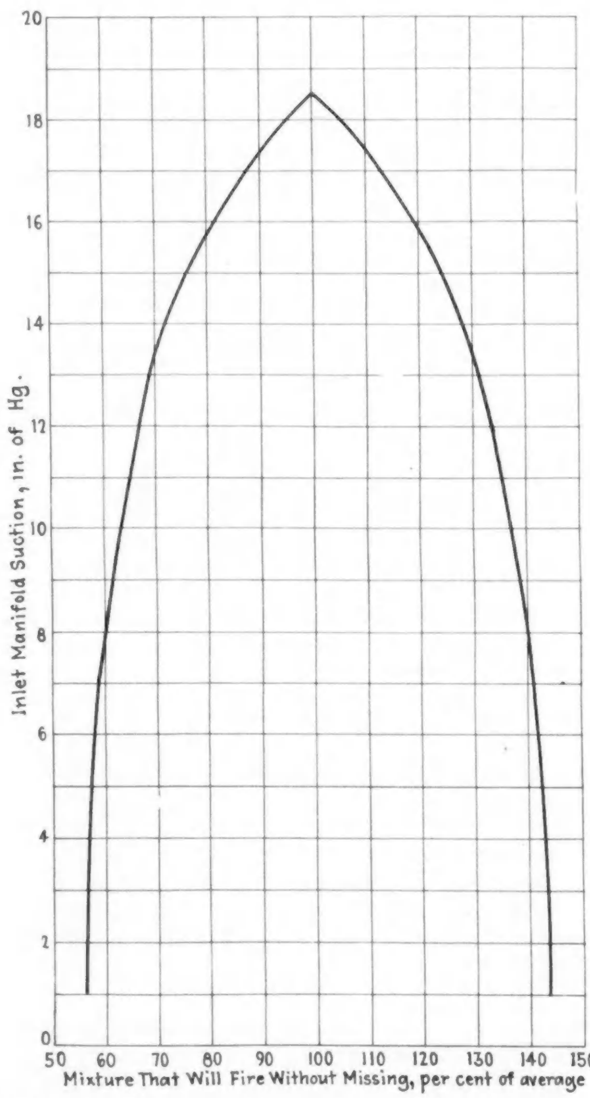


FIG. 41—RANGE OF MIXTURE FOR VARIOUS DEGREES OF INLET-MANIFOLD SUCTION

[38] M.S.A.E.—Director of engineering, carbureter division, Borg-Warner Corp., Flint, Mich.

and assure himself that he is doing the best he can in this respect.

Idling Depends on Mixture at Spark-Plug

Both theoretical considerations and the results of our tests indicate that this tendency of the engine to be unsteady at idle is due to the fact that the mixture at the points of the spark-plug when the spark passes is getting on the ragged edge of the firing range. A hotter spark will usually clear up the trouble, and we believe that this is because the hotter spark will ignite a poorer mixture. Twelve volts on a 6-volt ignition set will often cure a bad case of idle bucking, as will also separating the spark-plug points to 0.040 or 0.050-in. instead of the usual 0.018 to 0.025-in. setting. If this theory is correct, any considerable increase in the intake vacuum above the usual 18 or 19 in. of mercury should result in a serious upset in the regularity of the firing of the engine.

To try out this theory, we put an automatic CO_2 recorder on the exhaust manifold of the engine, believing that the percentage of CO_2 would decrease as missing increased. From physics we know that, when the suction in the inlet manifold is more than about 14.5 in. of mercury at a given throttle setting, the rate of flow of fuel and air through the carbureter will be substantially constant as the suction increases. If the carbureter adjustment is not changed, the mixture ratio will therefore not change and the change in CO_2 will be due entirely to the missing. We then increased the suction to as much as 25 in. of mercury by motoring the engine over with the dynamometer. As the suction increased above 19 in., the missing rapidly became much worse. The CO_2 was 15 per cent at 18.5 in. and about 5.5 per cent at 25 in. At these higher suctions, the exhaust manifold filled up with unburned fuel that had a disagreeable odor, making it perfectly clear that the difficulty of firing the mixture has a direct relation to the amount of suction in the inlet manifold. In this connection it is interesting to note that the engine tested idles with a suction of between 18 and 19 in. of mercury.

Manifold Vacuum Sets Idling Limit

These tests make it clear that one reason for the appearance of bucking at idle is the fact that the engine itself is fundamentally unable to fire any reasonably wide range of mixtures when the intake suction is as high as it is at idle. This situation comes about in this way: The suction at idle is about 19 in. of mercury. At the end of the exhaust stroke the combustion-chamber is filled with burned gases at slightly more than atmospheric pressure. When the inlet valve opens, these burned gases rush into the inlet manifold. As the piston descends, these gases are the first to be drawn back, and only the very end of the suction stroke yields a pure charge. If at the end of the compression stroke this small volume of new mixture is mixed with the burned gases or, worse still, concentrated at some point away from the spark-plug, it will be difficult to get positive ignition. An overlap between the inlet and exhaust-valve openings will make the condition still worse. As the vacuum above the piston is high at idle during the entire suction stroke and a part of the compression stroke, a small leak at the pistons will let in air enough to cause serious dilution since the new charge is so small. Finally, since the engine is critical at idle, the result of a small cylinder leak will be a serious case of bucking. This reasoning checks our experience exactly.

It is our opinion that the engine designer can do something to help this condition by so designing the combustion-chamber as to trap the last end of the incoming charge and cause it to be compressed right around the spark-plug. He should be able to get positive ignition in this way, even though the volume of the new mixture is very small and though it has been preceded by a large volume of highly diluted mixture and burned gases. Such an arrangement should enable him to fire a much smaller amount of new charge than is possible with our present designs. It should enable him to fire positively at a higher inlet-manifold suction and to use successfully mixtures that vary quite materially from the best proportions at normal idle suctions. This would result in steady idling that could be maintained in the field under a wide variety of driving conditions.

Since most of the driving of passenger-cars is done with very light loads on the engines, more stress should be put on details that produce good action at light torques. Tests for steady idling should be most carefully made in our development program for combustion-chambers, instead of being entirely omitted from them, and high importance should be attached to such tests.

ALEX TAUB:—I am glad that Mr. Berry spoke about high-speed missing, because its cause is the same as that of irregular idling. Perhaps Mr. Janeway has something to say on the question.

Getting a Good Mixture at the Spark-Plug

ROBERT N. JANEWAY[39]:—Mr. Berry, as a carbureter man, is entirely justified in disclaiming responsibility for both poor idling and high-speed missing, but I do not think that he is justified in passing the buck to the ignition man. The fact that increasing the spark-plug gaps improves conditions simply indicates that the mixture in the neighborhood of the spark-plug is at the limit of inflammability. We know that the only time when the hotness of the spark really affects combustion is when the mixture is on the ragged edge. I think that the carbureter is not involved. Correction for both conditions must be sought both in manifolding and in combustion-chamber design, and the most important thing in the latter connection is the location of the spark-plug with respect to the inlet valve.

In a paper[40] that I have written, I showed a diagrammatic comparison between a good and a bad condition. A fairly representative combustion-chamber, like that shown in Fig. 2 of that paper, having the spark-plug at the top of the dome over the inlet valve, gives about as poor a condition as possibly could exist both for idling and for high-speed missing, because only a little of the charge coming out around the inlet valve sweeps past the plug, and its velocity is very low at that point.

The first correction to make is to move the plug away from the inlet valve, toward the exhaust valve. Then the main blast of charge entering around the valve has an opportunity to sweep over the spark-plug. Reducing the height of the chamber over the valves brings the plug nearer to the high-velocity path of the incoming charge. Both of these conditions will tend to elimi-

[39] M.S.A.E.—Consulting engineer, Detroit.

[40] See S.A.E. JOURNAL, May, 1929, p. 498; TRANSACTIONS, Vol. 24, 1929, p. 141.

nate a stratification of exhaust diluent in the neighborhood of the spark-plug points.

FLOYD F. KISHLINE[41]:—I should like to mention an experience which indicates that idling is affected more by the overlapping of the openings of the inlet and exhaust valves than by the location of the plug. We used a rather wide variation in the location of the plugs, with hardly a perceptible effect on the ability of the engine to idle. But when the valve openings overlapped, allowing a breathing through from the exhaust ports into the combustion-chamber, the difference was marked. It is a fact that conditions are rather difficult in a combustion-chamber in which the dilution of the new charge when the engine is running wide open is approximately 20 per cent and considerably over 100 per cent when it is idling; we must burn through a lot of ashes to get the gas to burn.

American Experience with English Ideas

ARTHUR W. POPE, JR.[42]:—In general, from our experience with combustion-chambers, the compactness determines the highest practicable compression-ratio. The flatter and longer we get the chamber, the lower the compression ratio must be. We felt rather badly when we first read Whatmough's articles denying these points, but we did not feel so badly after we had tried out his ideas.

We have found the amount and the height of the clearance space between the piston and the cylinder-head to be the most important factors controlling combustion speed; much can be done by varying those factors. Ricardo recommends a close clearance with a considerable amount of shielded area, which ordinarily gives rapid combustion. He secures soft action by means of the pocket for the spark-plug, which Mr. Taub illustrated.

MR. TAUB:—Mr. Berry pointed out that the mixture became critical as the manifold vacuum increased. Valve overlap has the same effect. After all, it was not the vacuum that made the trouble, it was the exhaust-gas diluent. The result is the same whether the excessive diluent is caused by inlet-manifold vacuum or from valve-overlap. Nevertheless, it is easy to disturb the idling performance even in an engine that has fairly good valve timing.

An example of this was our experience with the present Chevrolet combustion-chamber form in a small-bore engine. It was necessary to make the pocket very narrow, because of the small displacement. The carbureter man was unable to eliminate missing.

We eliminated the trouble by starting the engine with increased battery voltage and then by increasing the spark-plug gap from 0.022 to 0.042 in. We finally remedied the trouble by making the pocket wider at *A* and not so deep at *B*, in Fig. 42. There was no trouble with idling when the conditions for burning were made right at the spark-plug.

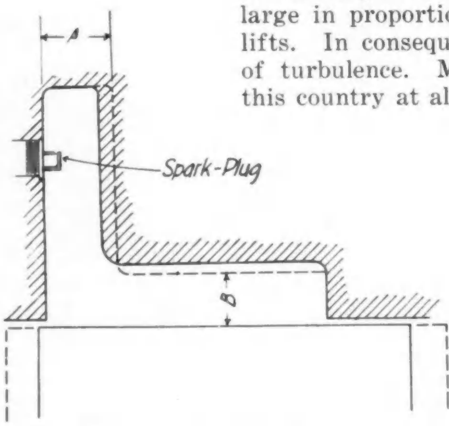


FIG. 42—MODIFICATION OF SMALL-BORE ENGINE

The Original Head of the Engine with Small Bore Missed in Idling. Dotted Lines Show Changes That Remedied the Trouble

Ricardo Agrees to Most Points

HARRY R. RICARDO[43]:—I have read Mr. Taub's paper with great interest, but there is no time to look up references or to do more than generalize if my comments are to be received by you in time for publication with Mr. Taub's paper.

In the first place, I should like to thank Mr. Taub most heartily for the generous and kindly way in which he has treated me and for the painstaking care with which he has sorted out my beliefs. In the second, I am rather horrified to see how appallingly effusive I must have been. After reading over Mr. Taub's careful analysis, the first point that occurs to me is that Janeway and I are, I believe, really in better accord than Mr. Taub suggests; not only are our conclusions substantially similar but our reasoning also.

I do not think that Mr. Taub allows quite fully for the great lapse of time and the great changes in the state of the art since I started on this theme during the War. At that time most engines, and in particular L-head engines, were fitted with valves that were very large in proportion to their speed, and with very low lifts. In consequence they suffered acutely from lack of turbulence. Moreover, there was at that time, in this country at all events, rather a lack of appreciation of the value of turbulence, as a means of speeding up combustion and in other respects also, hence my insistence on turbulence and on supplementing the normal turbulence of induction. As time went on and engine speeds increased—without any increase in the size of valves, which were already as large as space would permit, also with the general tendency to use higher lifts and better-shaped ports—the need for supplementing the normal induction turbulence diminished and today is hardly felt. Moreover, the part played by turbulence is now generally recognized and appreciated by all, hence my lack of insistence on this factor in later papers. In the case of present engines of uptodate design and proportions, I agree with Janeway that the shape of the combustion-chamber matters little so far as thermal efficiency at any given compression-ratio is concerned, but this certainly was very far from being the case 12 or even 6 years ago.

Present proportions give virtually all the turbulence that we require, for full-throttle running, at all events. We no longer have the same need to supplement it by means of a restricted passage, nor can we now afford a restriction sufficient to affect greatly the turbulence without obstructing the breathing capacity of the engine. No mention is made, however, of the final turbulence produced by the ejection of the mixture entrapped between the piston and head; this is quite considerable, so considerable indeed as to play a vital part when applied to high-speed Diesel engines.

Again, with regard to the necessity of keeping the last gas to ignite as cool as possible, I have always re-

[41] M.S.A.E.—Assistant chief engineer, Graham-Paige Motors Corp., Detroit.

[42] M.S.A.E.—Research engineer, Waukesha Motor Co., Waukesha, Wis.

[43] F.M.S.A.E.—Technical director, Ricardo & Co., Ltd., Old Shoreham, Sussex, England.

garded this as very important, and I thought that I had insisted on it from the very start. I made a very strong point of this in a book[44] written in 1921 and 1922, and on many other occasions[45].

End-Wall Shape Is Unimportant

With regard to the form of the "end-wall" of the combustion-chamber, I showed in my paper read in New York a section of an actual English engine with a long, sloping end-wall to the combustion-chamber. In consequence of this illustration, it has been assumed that I was wedded to this form. It was, in fact, purely fortuitous. I myself can find no advantage nor can I detect any difference whatever between a sloping end-wall and an absolutely perpendicular one such as Janeway prefers, and I have come to use the perpendicular wall in cases where the combustion space is machined by end-milling and the sloping wall when unmachined or machined by a formed cutter; in other words, I have regarded this feature purely as one of manufacturing expediency.

Mr. Taub is a little surprised as to why I urged that the depth of the clearance space above the piston was "critical" seeing that over the range of gasket thickness the effect was small. My reason for this was that I had recently been consulted on several new European engine designs in which the top of the piston was free from 1/8 to 3/16 in. below the top of the block, and this, together with the gasket clearance, would have passed the critical depth. I agree that it is not critical so long as the top of the piston comes flush with the top of the block, but I felt that attention should be called to this point in view of the practice of dropping the piston.

With regard to control of the area of flame front, we did carry out a series of investigations along this line some seven years ago, more particularly in connection with sleeve-valve engines, which suffer so acutely from over-turbulence and consequent roughness. About six years ago we designed a six-cylinder sleeve-valve engine, which was built by Vauxhall Motors, in which the area of flame front was controlled in the way Janeway suggests, following exactly the same line of reasoning. At the time of its introduction on the market the engine was fully described[46] and the somewhat peculiar form of combustion-chamber was much commented upon in the technical press. It certainly gave very smooth running and at the time was about the only sleeve-valve engine that was free from the well-known distressing drumming sensation.

The only real point of difference between Janeway and myself seems to lie in our methods of testing for detonation values. Janeway uses border-line ignition advance. I have found this method very misleading and had to abandon it; so, too, have most experimenters in this country. Where variable compression cannot be employed, the next best thing appears to be the use of graded fuel mixtures whose detonation characteristics can be checked and calibrated in a variable-compression engine. I find that it is at all times very essential to be able to work over and beyond the whole useful range of ignition timing, especially when investigating smoothness of running.

Quantum Theory Supersedes Thermodynamics

W. A. WHATMOUGH[47]:—My discussion will be concerned only with my own activities and the interpretations thereof.

The objection that I am difficult to understand applies equally to all modern heat theories. Taub stresses the utility of mathematical thermodynamics in combustion-chamber progress, despite the fact that thermodynamics is virtually superseded in the newer sciences by the quantum heat theory.

Irving Langmuir, one of America's scientific geniuses, is not only a chemist but a practical physicist. The following are excerpts from his presidential address to the American Chemical Society in September, 1929:

> Most of our misunderstandings in science arise from assigning reality to concepts whose main reason for existence is the fact that they are represented by a word. Logically we should aim to define our words in terms of operations.[48]
>
> There are many cases where the concept of temperature has no definite meaning. Strictly speaking, temperature acquires meaning in terms of operations only in so far as an approach is made to equilibrium conditions.[49]
>
> It was thought that such concepts as energy, entropy, temperature, chemical potential, and so forth, represented something far more clearly absolute in character than the concept of atoms and molecules. We must now recognize, however, that all of these concepts are human inventions and have no absolute independent existence in nature.[50]
>
> Unfortunately, although theoretical physics and chemistry are thus supplementing each other and in many respects are being merged into a new science, there are remarkably few men as yet that have received adequate training in both sciences. To pave the way for the coming revolutionary changes in chemistry we must be prepared to modify our methods of thinking, probably along lines now so prevalent in physics.[51]

In face of Langmuir's statements and the foregoing facts, how can one agree with Taub's fundamentals? Like scientists in general, I am searching for the truth. I began in 1923 to think of the processes of chemical combustion in terms linking these with the physical emission of radiant energy. The origin of this line of endeavor was due to the fact that the working of a double-diaphragm governor for controlling mixture quality, independent of the temperatures and/or pressures of fuel and air, the constituent components, worked contrary to the kinetics of gas.

Such quality control depends upon velocity effects, and my first paper[52] presented to automobile engineers, in 1922, dealt with such fundamentals as the prime factors of flow of gases and the limiting conditions for the quality control of combustible mixtures.

Taub makes the mistake of accepting thermodynami-

[44] See The Internal Combustion Engine, by Harry R. Ricardo, Vol. II, pp. 90 and 96; Blackie & Sons, Ltd., London, 1923.

[45] See Engine of High Output, by Harry R. Ricardo, pp. 56 and 87; Macdonald & Evans, London, 1926.

[46] See *The Automobile Engineer*, January, 1926, p. 23.

[47] Consulting and research chemist, New Barnet, England.

[48] See *Journal of The American Chemical Society*, October, 1929, p. 2856.

[49] See *Journal of The American Chemical Society*, October, 1929, p. 2858.

[50] See *Journal of The American Chemical Society, October*, 1929, p. 2861.

[51] See *Journal of The American Chemical Society*, October, 1929, pp. 2867 and 2868.

[52] See *Proceedings of Institution of Automobile Engineers*, 1922, Vol. 17, Part 1, p. 346.

cal hypotheses, which are purely imaginary concepts, as definite working principles.

Mathematics Depends on Observations

Mathematics in science can only be subservient to actual observations, and the adaptation of an adiabatic exponent to make an equation fit a predetermined temperature-pressure curve is merely a mathematical exercise and not an explanation of the underlying heat principles. I have shown[53] that the same result for chemical reaction rate can be obtained from four wholly different heat theories: gas kinetics, thermodynamics, quantum theory, and activated molecules.

Taub's statement that my work "appears to us mostly in the abstract" is unjustifiable in view of my very complete compendium[54] on combustion and its working principles appearing at the conclusion of a series of articles on Detonation, which was published in *The Automobile Engineer,* throughout the year 1927. This summarizes the gist of those articles in customary engineering technology, alongside of their physicochemical significance.

Every care was taken in this summary to give due credit to each investigator, even to the extent of printing known principles in larger type and my deductions and addenda in smaller type. Taub adopts the simplified synopsis appearing in my S.A.E. paper of 1929, in which references to the originators of the principles in question were necessarily omitted in the process of simplification.

Various theories on flame travel have been wrongly attributed to me because of my descriptions that were based upon the results of work done by other investigators. Taub's criticisms would be more apropos and valuable if he had studied the original articles more closely. Flame propagation is undoubtedly a complicated subject, but the lack of clarity complained of by Taub is due to not following up the references given in the compendium to which I have referred. Definitions 6 and 20 of the original compendium set out with scientific accuracy of statement Whatmoughisms 2 and 3 of the simplified synopsis on flame propagation in my S.A.E. paper which are befogging to Taub.

Taub has undertaken a difficult task in attempting to elucidate factors common to three exponents having decidedly different ideas regarding combustion-chamber design. The writer has been asked to give his agreement or disagreement with the five common factors which Taub considers are embodied in the cylinder-heads of Ricardo, Whatmough and Janeway.

Whatmough-Hewitt combustion-chambers may vary in shape, because, as Taub deduces, their design may be changed considerably so long as heat transfer is controlled.

Comment on Five Design Features

(1) *A cooling clearance space,* preferably of gasket thickness, is included wherever possible. This is arranged to be as extensive as possible, consistent with the desired breathing capacity of the engine.

The Whatmough principle of directional firing embodies progression of flame from hotter to cooler zones in a combustion-chamber; and, as Taub presumes, there is its equivalent when the cooling clearance space is absent. In my opinion, considerable quenching of flame occurs in the cooling clearance space. It is also agreed that a "thin" cooling clearance space is likely to become detrimental, owing to the onset of roughness of running when entry thereto is choked with carbon.

(2) *Spark-plug location* over the exhaust valve is definitely included in the Whatmough principle of directional firing.

The object of this is to start ignition in a dry mixture and burn first the portion that is most liable to autoignition.

Incidentally, in any later designs embodying differential water-cooling, the spark-plug boss has been moved decidedly forward and much nearer the center of the exhaust valve.

(3) *Non-Compact Combustion-Chambers.* Whatmough-Hewitt combustion heads are, wherever possible, of the non-compact type.

The prime object is to differentiate between a hot zone containing the exhaust valve and ignition device and a cooler zone toward which flame progresses. No attempt is made to fix any definite surface:volume ratio. The dimensions of the combustion-chamber are primarily determined by considerations of gas and/or flame flow. With high compression-ratios, the combustion-chamber becomes as flat as volumetric efficiency will permit.

(4) *Volume control* for smoothness does not enter into the calculation of contours of a Whatmough-Hewitt combustion head.

(5) *Flame Shock.* I am in general agreement that the rate of pressure rise is a measure of flame speed, and consequent liability to rough running.

However, smoothing of flame speed and of pressure rise by combustion-head design connotes also excellent distribution and accurate carburetion.

The main criticism of Taub's conclusions is that he limits himself to considerations based upon combustion-chamber shape rather than to its particular functions.

Heat Exchanges Occur During Whole Cycle

Taub concentrates upon a small part of the Otto cycle; namely, the interval between spark ignition and peak pressure. This concerns only about 1/20 of the period during which heat exchanges are being effected in the combustion-chamber. It is true that engine detonation occupies only about 1/200 of a cycle, but the events leading thereto occur during the whole cycle.

I differ from other investigators in paying attention to heat exchanges operative throughout the whole cycle of combustion. In particular, I strive to control roughness by regulating the cooling and heating effects in the engine as a whole and not by combustion-chamber design alone. The constant endeavor is to keep the rate of burning within practical limits, represented by the onset of autoignition under full load and unduly slow burning when running light.

When I stress the importance of avoiding turbulent heating, I am referring to an exhaust period occupying one-third of the Otto cycle. My objection to the turbulent type of combustion head is that baffling must introduce eddies into the flow of the exhaust gases, which in turn causes overheating of the exhaust-valve head. The heating effect of an exhaust-valve head extends over one-half of a cycle, during induction and compression. With the valve head at say 800 deg. cent. (1472 deg. fahr.) this effect will be nearly double what

[53] See *The Automobile Engineer,* September, 1927, p. 346.
[54] See *The Automobile Engineer,* December, 1927, p. 502.

it is when the temperature is about 600 deg. cent. (1112 deg. fahr.).

Again, the effect of water-cooling extends throughout the whole of the two engine revolutions comprising the cycle; therefore it can be arranged to have the greatest effect in that control of combustion which is brought about by the regulation of the heat exchanges between the combustible and its surroundings.

It would require a separate treatise to deal adequately with the various considerations entering into the design of a Whatmough combustion head. Sufficient to say, these are based upon variations present in the flow effects of unburned and burning combustible and not upon nominal gas velocities or calculated pressures in which localized differences are lost by mathematical averaging.

Principles Embodied in New Design

More convincing proof of the soundness of the Whatmough principles of combustion control than any amount of argumentation by the inventor are formed in recent unbiased and independent reports[55] showing what has been achieved in smoothing engine performance in an A. J. S. engine which is the first design embodying my principles in full. It is fitted with a "director" head incorporating the following patented features: (*a*) directed intake, (*b*) directional firing, (*c*) streamlined exhaust and (*d*) differential water-cooling. The extraordinary effect of differential water-cooling in smoothing engine performance is proved by the increasing roughness when a director head is fitted to an unmodified cylinder-block.

Taub in his conclusions stresses the utility of a cooling clearance space and agrees with placing the sparkplug in the neighborhood of the exhaust valve. The combination of these two factors is the Whatmough principle of directional firing.

Taub abandons turbulent eddying of the intake as a means of controlling flame speeds; yet turbulence does enter into combustion-chamber progress, the difficulty being to control its detrimental effects.

Turbulence, or rather turbulent heating, is used in a Whatmough director head to accelerate slow-speed torque and make provision for an extraordinarily even tick-over.

However, Taub shows signs of assimilating my principles of heat exchanges when he states that obviously both Ricardo and I may be right in regard to the effects of turbulence according to whether the scouring action is applied to heating or cooling surfaces.

Control is the basis of my principles, and this is self-evident in my inventions and technical papers, which range from a quality-control gas governor, patented in 1917, to control of carburetion, patented in 1926, as a preliminary to the combustion-chamber patents of 1927 to 1930. The latest developments concern improvements in the breathing capacity of gasoline engines.

Advantages of Mathematical Method

MR. JANEWAY:—All those who are interested in the subject of combustion-chamber development must feel indebted to Mr. Taub for so nobly achieving order in a situation which threatened to become a muddle of contradiction and controversy. He has exposed the writings of Ricardo, Whatmough and myself to a searching process of alternate boiling and sifting, evaporating the excess verbiage and condensing the subject matter to its essence of underlying thought. Considering the bulk of the accumulated writings, one must marvel at the patience and courage that made this review possible.

Mr. Taub has conclusively shown that, in spite of differences in theory and method of approach, the three investigators in question have arrived at certain common features of design which must be accepted as indispensable to satisfactory combustion characteristics, namely:

(1) Offsetting, to provide a high degree of cooling of the residual unburned gas, which is essential for anti-detonation effect

(2) Non-compact main chamber with relatively long flame travel secured by plug location near valves, which is essential for smoothness

Mr. Taub endeavors to show further that the principle of volume control is also common to the designs of all three men. I, for one, do not find this conclusion convincing. The principle of volume control, as a means of securing proper variation in the rate of pressure rise, is the one factor which cannot be embodied in a combustion-chamber by haphazard or cut-and-try methods, but inherently requires deliberate, painstaking calculations based on the fundamentals of reaction rate. The pressure-time characteristic of the burn is so sensitive to comparatively slight changes in the chamber design that no real similarity of result could be achieved by the wide differences in detail of chamber shape which are to be found in the designs of Ricardo, Whatmough and myself. The representative indicator-cards analyzed by Mr. Taub certainly do not show any approach to a common antishock result, as he admits.

The one factor which does stand out is that relative smoothness, as observed, follows the indicated acceleration in the rate of pressure rise. The essential difference between the results of Ricardo and Whatmough and those which I have obtained is that the other investigators obtain improvement in smoothness by cut-and-try changes which unconsciously operate upon the acceleration in rate of pressure rise, while I deliberately keep this factor to the minimum by design. Considering the infinite number of variations possible in the chamber shape, it is inconceivable that the same degree of smoothness can ever be obtained by haphazard design which can be achieved by the scientific method of attack.

MR. TAUB:—The discussions of this paper are most gratifying.

Our objective was to prove that in the main there exists very little difference in the final result of these investigators. The discussions support this fact. Ricardo and Janeway subscribe completely to this contention. Whatmough agrees substantially, but demurs on the fact that insufficient consideration has been given to the physico-chemical.

Whatmough must remember that the average automotive engineer, such as the writer, has an extremely limited understanding of this vague art which, in itself, is changing so rapidly that even its proponents with difficulty keep up with the parade.

I am deeply grateful to Messrs. Ricardo, Whatmough and Janeway: First, that they have worked as they have; second, that they have cooperated so graciously; and, third, that they have discussed this review of a portion of their work.

[55] See *The Light Car and Cyclecar*, Aug. 1, 1930, pp. 298 and 304, and *The Autocar*, Aug. 1, 1930, p. 235.

The Effect of Airplane Fuel-Line Design on Vapor Lock[1]

Semi-Annual Meeting Paper

By Oscar C. Bridgeman[2] and Hobart S. White[3]

The study of fuel flow in gravity-feed systems, which has hitherto been confined to flow through simple orifices, has been extended to include the measurement of flow through systems of various designs. The results of this study indicate that variations in the cross-sectional area of the feed lines from that at the tank outlet may have a marked effect on the vapor-locking tendency. Constrictions in the line and increases in cross-sectional area along the direction of flow are particularly liable to cause trouble from vapor lock. Experiments with commercial carbureters show that weathering of the gasoline in the carbureter float-bowl reduces the vapor-locking tendency of the fuel and, under certain conditions, may even cause an increase in the flow through the jet.

THE fuel-feed systems used in airplanes may be divided into the two general classes: gravity-feed systems and pressure-feed systems. Various combinations of these have been satisfactorily employed, and numerous modifications in details of design and installation have been introduced to meet the requirements imposed by the available space and the general airplane design. Preliminary work on flow through fuel-feed systems indicated that apparently minor changes might appreciably affect the tendency toward vapor lock, and a more detailed study of some of these design factors was undertaken. The results obtained are suggestive, rather than indicative, of the best type of fuel system to be used. The general conclusions reached may be summarized as follows:

(1) Although the use of a pressure-feed system employing a fuel pump eliminates most causes of vapor lock on the pressure side of the pump, it does introduce a serious tendency toward vapor lock on the suction side of the pump, which is not inherent in gravity-feed systems.

(2) Careful design and installation of the feed lines in a gravity-feed system can assist materially in reducing vapor-locking tendency. This involves the elimination of all unnecessary bends, the use of sufficiently large tubing and the avoidance of such changes in cross-sectional area of the feed line as would assist in the retention of bubbles of air or vapor, with consequent reduction in the hydrostatic head of liquid.

(3) Weathering of the gasoline in the carbureter float-bowl automatically tends to prevent vapor lock in the carbureter and, in fact, may enrich the mixture, due to development of pressure above the gasoline in the float-bowl.

Subdivision of Flow Experiments

The experimental work which has been done at the Bureau of Standards on flow through fuel-feed systems can be subdivided into the investigations of:

(1) Flow under gravity to an orifice without the insertion of a float-bowl and with an "ideal" installation of the feed line

(2) Flow under gravity to an orifice without the insertion of a float-bowl but with variations in the installation of the feed line

(3) Flow under gravity to a carbureter float-bowl with heating between the float-bowl and an orifice

(4) Flow under gravity to standard makes of carbureter

(5) Flow to a standard gear fuel-pump by suction lift.

The results obtained and the conclusions reached in the study of these various phases of the investigation of gasoline flow through fuel-feed systems will be discussed in the order named. Distillation curves are shown in Fig. 1 for the fuels 184 and 194 used in the fuel-pump experiments and for fuels 504 and 154 used in connection with the gravity-flow experiments.

Fixed Gravity System without Float Bowl

In a recent report[4] experimental data were presented on the flow of 22 fuels through a simple gravity system consisting of a tank joined to an orifice by means of a copper feed-line of uniform cross-section and with only one bend, which might be considered as an "ideal" feed-line installation. The carbureter was omitted in these preliminary experiments to avoid the complications involved in maintaining a pressure difference between the float-bowl and the jet. Provision was made for heating the gasoline flowing to the jet and, with each fuel, the rate of flow was determined over a range of temperature and at the three pressures, 760, 570 and 380 mm. (29.92, 22.44 and 14.96 in. respectively) of mercury, corresponding to sea level, 8000 ft. and 18,000 ft. altitude. The vapor-locking temperature was taken as the temperature at which the rate of flow began to change rapidly as the fuel temperature was increased. The observed vapor-locking temperatures were in good agreement with the temperatures at which the vapor pressures of the gas-free gasolines equaled the external pressure in each case. For fuels free from propane,

[1] Publication approved by the Director of the Bureau of Standards of the United States Department of Commerce.

[2] S.M.S.A.E.—Research associate, Bureau of Standards, City of Washington.

[3] Junior physicist, Bureau of Standards, City of Washington.

[4] See S.A.E. JOURNAL, July, 1930, p. 93.

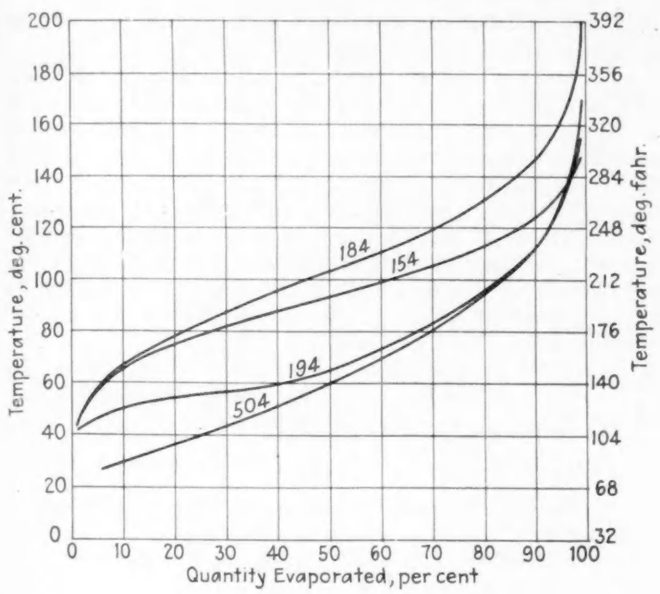


FIG. 1—DISTILLATION CURVES FOR FUELS 184 AND 194 USED IN FUEL-PUMP EXPERIMENTS AND FUELS 154 AND 504 USED IN GRAVITY-FLOW EXPERIMENTS

which is usually the case with aviation gasolines, the predicted vapor-locking temperatures can be obtained by a rearrangement of the general vapor-pressure relation[5] to give

$$t = \frac{A\, t_{10\ per\ cent} + 273.1 \log\ (p/760)}{A - \log\ (p/760)} \qquad (1)$$

in which $A = 4.45 + 3.8 \times 10^{-3}\, t_{10\ per\ cent} - 0.6\sqrt{S}$.

In this equation, t is the vapor-locking temperature in degrees centigrade; $t_{10\ per\ cent}$ is the A.S.T.M. temperature at 10 per cent evaporated, also in degrees centigrade; p is the pressure on the gasoline in the fuel line, expressed in millimeters of mercury; and S is the slope of the A.S.T.M. curve at the 10-per cent point, expressed in terms of degrees centigrade change per unit change in the percentage evaporated.

If the Reid method is used to measure the vapor pressure at 100 deg. fahr., which is preferable to computation from the distillation data in the case of propane blends, the vapor-locking temperature in degrees fahrenheit is given by the relation

$$t = 560 \left[\frac{5.167 - \log\ p_R}{5.167 - \log\ p}\right] - 460 \qquad (2)$$

where p_R is the measured Reid vapor pressure at 100 deg. fahr, multiplied by the factor 1.1, and p is the atmospheric pressure at the given altitude, both in pounds per square inch.

Experiments were also made with different sizes of orifice, with submerged and open jets and with different rates of flow through the system, and in all cases the observed vapor-locking temperatures were in good agreement with those computed from Equation (1) or (2).

Effect of Variations in the Fuel-Feed Line

In the work with the simple gravity system, it was observed in some cases that changes in the feed line, such as bends or constructions, exerted a marked effect on the rate of fuel flow. Accordingly, a number of variations were made in the installation of the feed line between the tank and the jet, and flow experiments were made with each set-up at temperatures considerably below those at which vapor lock occurred in the original installation. This original installation is shown in Fig. 2, which is reproduced from a previous report[6]. The inner compartment of a was used as the reservoir for holding the gasoline during the flow experiments and was provided with an opening to the pressure-control system. The gasoline flowed out of the tank through a copper tube to the orifice d and was heated during passage by means of the jacket b, through which heated oil was circulated by means of a pump. The nickel resistance-thermometer c was used to measure the temperature of the gasoline. After the liquid passed through the orifice it was cooled in the condenser e and the weight of gasoline collected per unit time in any desired one of the containers g was determined.

The variations in the fuel line were made between the container a and the jacket b; and the remainder of the set-up was identical with that shown in Fig. 2. Diagrams of these changes are illustrated in Fig. 3, representing (a) vertical outlet, (b) decrease in the cross-sectional area, (c) constriction in the line, (d) constriction at outlet from tank, (e) elbows at outlet from tank, (f) siphon in the line and (g) bends in the line. In this figure, the diameters of the

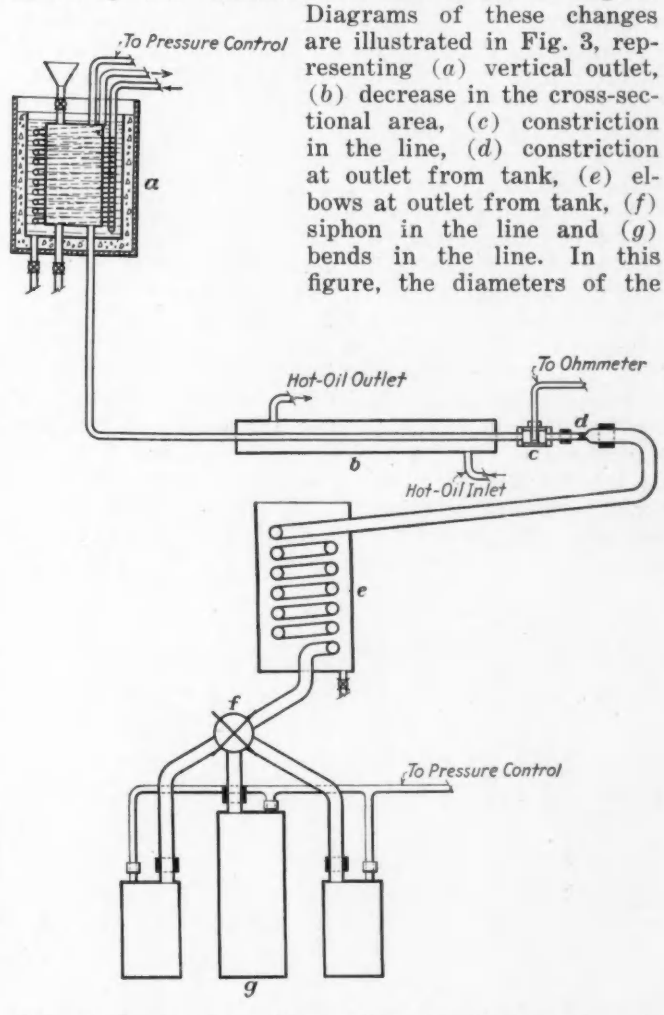


FIG. 2—DIAGRAM OF SIMPLE-GRAVITY SYSTEM USED TO DETERMINE EFFECTS OF VARIATIONS IN THE FUEL-FEED LINE

The Inner Compartment of a Held the Gasoline and Had an Opening to the Pressure-Control System. Fuel Flowing Out of a Was Heated by the Hot-Oil Jacket b. The Resistance-Thermometer c Indicated the Gasoline Temperature. After Passing Orifice d, the Fuel Was Cooled in Condenser e, and Weight of the Gasoline Collected per Unit Time in Any Desired One of Containers g Was Determined. Variations in the Fuel Line, as Shown in Fig. 3, Were Made between Container a and Jacket b

[5] See S.A.E. JOURNAL, July, 1930, p. 95.
[6] See S.A.E. JOURNAL, August, 1930, p. 222.

tubing shown in the various installations are drawn to scale. Flow experiments were made in each case with fuel 154 at 760, 570 and 380-mm. (29.92, 22.44 and 14.96-in. respectively) pressure and at temperatures below those at which vapor lock normally occurred. The data obtained, expressed in gallons per hour, are shown in Table 1. The fuel flow for system (*a*) represents the normal flow at the three pressures.

The results given in Table 1 are specific for each system. A decrease in the size of tubing, as in (*b*), cuts down the flow by a small amount, whereas a constriction in the vertical line from the tank, as in (*c*), has a marked effect on the flow. A change from a small tube to a larger tube at the outlet from the tank, used in system (*d*), reduces the flow greatly at all pressures, due to collection of bubbles in the tube below the enlargement, with consequent reduction in the head of liquid on the jet. Elbows in the line at the tank have an effect similar to an enlargement in the line, but the average effect is not so marked. The siphon in system (*f*) did not reduce the flow noticeably during the time required for the flow measurements, due presumably to the smoothness and large curvature of the bends, but might constitute a bad air-trap under other conditions. The distorted system in (*g*), with several bends, did not affect the flow until a pressure slightly higher than 380 mm. (14.96 in.) was reached; then the flow decreased almost to one-third of its original value.

In this group of experiments with various designs of feed line, glass tubing was employed so that the formation of bubbles and their rate of elimination from the feed line could be observed. In every case it was found that bubbles of air or vapor formed in the line and tended to move upward against the stream of liquid. This bubble formation resulted from a slight increase in temperature of the fuel after leaving the tank, and the number of bubbles formed increased with decreasing pressure. It was noticed that the effect of design on the flow largely resulted from the restrictions imposed on the elimination of this gas or vapor. If the vapor escaped readily, no reduction in flow was observed. If, however, the vapor tended to collect, the hydrostatic head of liquid was reduced and hence the flow of gasoline was decreased.

It is concluded from these results, obtained with various installations, that an increase in the cross-sectional area of the feed line along the line of flow may have a marked effect in decreasing the flow, and hence should be avoided in actual systems. A decrease in the cross-sectional area, of the type shown, appears to have only a small effect on the flow, but obviously the size cannot be reduced beyond certain limits. Further, unnecessary bends in the line, particularly if sharp, appear to be undesirable and may have considerable effect at low pressures. While the experiments outlined were not made under vapor-locking conditions, in order to obtain comparability between the results, the conclusions should be applicable to such conditions.

Effect of Heating between Float-Bowl and Jet

Preliminary to making flow experiments through actual carbureters, a number of measurements were made with a carbureter float-bowl between the tank *a* and the oil jacket *b* in Fig. 2. This amounts to heating the gasoline between the float-bowl and the jet. Two effects were studied: the suction on the jet, and the angle of inclination of the tube between the bowl and the jet. In these experiments, a differential manometer was placed in a line leading from the top of the carbureter float-bowl to the exit side of the jet, and, by means of valves, a constant pressure-difference could be maintained at any desired absolute pressure.

In the first series of measurements, the flow was measured over a temperature range with fuel 154 at 380, 570 and 760-mm. (14.96, 22.44 and 29.92-in.) pressure and with suctions of 25 and 50 mm. (0.984 and 1.968 in.) of mercury on the jet in each case. The data obtained are shown graphically in Fig. 4, in which the relative time for a given volume of flow is plotted against the temperature in degrees centigrade. The dash lines at each pressure are the curves obtained previously without the carbureter float-bowl and without any pressure difference across the jet. The vapor-locking temperatures predicted from Equation (1) are indicated on each curve by means of arrows, correction being made for suction on the jet. The agreement between the observed and calculated vapor-locking temperatures is good, so that, if correction is made for the pressure difference between the float-bowl and the jet, Equation (1) can be used to compute the temperatures at which vapor lock can occur under the given experimental conditions.

In the second series of experiments, a constant suction of 25 mm. (0.984 in.) of mercury was used on the jet, but the line between the float-bowl and the jet was successively inclined upward 12.5 deg., placed horizontal and inclined downward 12.5 deg. These three positions simulated a climb, level flight and a glide. The results are shown graphically in Fig. 5. Within experi-

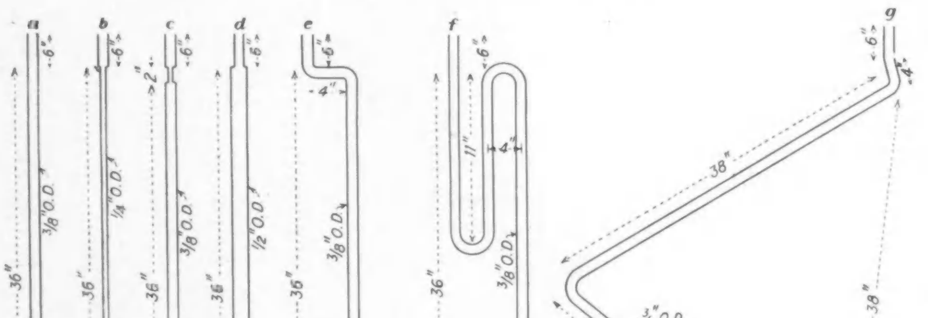


FIG. 3—DIAGRAMS OF CHANGES MADE IN THE FUEL LINE

The Diameters of the Tubing Used in the Various Installations Are Drawn to Scale. *a*, Vertical Outlet; *b*, Decrease in Cross-Sectional Area; *c*, Construction in the Line; *d*, Constriction at Outlet from Tank; *e*, Elbows at Outlet from Tank; *f*, Siphon in the Line; *g*, Bends in the Line

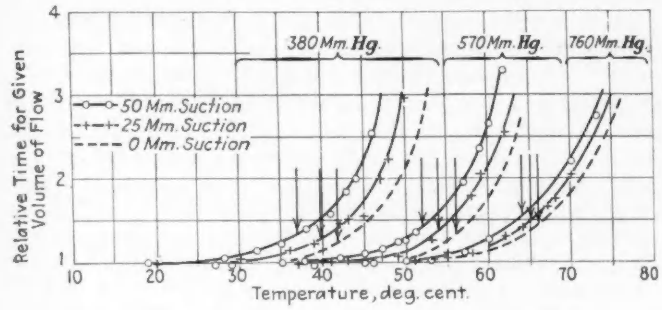


FIG. 4—EFFECT ON FUEL FLOW OF SUCTION ON THE CARBURETER JET

The Dash Lines at Each Pressure Are Curves Obtained Previously without the Carbureter Float-Bowl and without Any Pressure Difference across the Jet. Suction of 25 and 50 Mm. (0.984 and 1.968 In.) of Mercury on the Jet Was Used in Each Case

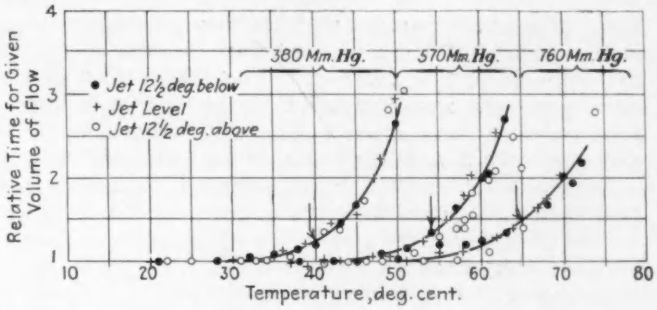


FIG. 5—EFFECT ON FUEL FLOW OF ANGLE OF INCLINATION OF TUBE BETWEEN FLOAT-BOWL AND JET

The Three Positions of the Jet Simulated the Positions of the Metering Orifice in an Airplane during Climb, Level Flight and a Glide. A Constant Suction of 25 Mm. (0.984 In.) of Mercury Was Used on the Jet. In Both Fig. 4 and This Figure the Arrows Indicate the Vapor-Locking Temperatures on the Curves Predicted from Equation (1), Corrected for Suction on the Jet

mental error, the inclination of the line does not appear to affect the flow at 380, 570 or 760-mm. (14.96, 22.44 or 29.92-in.) pressure.

Carbureter Experiments

Flow measurements through three commercial carbureters, made by two different concerns, were carried out in a gravity-feed system. The hydrostatic head of gasoline on the carbureters was fixed in each case at about 1 lb. per sq. in., and the suction on the jet was adjusted for each carbureter. Two different sets of experiments were made, one set on all three carbureters using the standard vent on the float-bowl and the other set on one carbureter using a vent considerably larger than that ordinarily employed. In these experiments the opening above the throttle valve was closed in each case by a plate and the closure made tight with a gasket. The air opening was also closed with a plate equipped with a drain tube to draw off the gasoline which passed through the jets. Suction on the jet was maintained by means of a tube through the top plate leading to the vacuum line. Heating of the gasoline was effected in the line just before it entered the float-bowl.

In the first set of experiments, each carbureter was used with the standard vent on the float-bowl. Examples of temperature-flow curves with fuel 504, a grade-A natural gasoline, are shown in Figs. 6, 7 and 8. The carbureter used for the results shown in Fig. 6 was a double-barrel type. The upper curve applies to flow through the carbureter, whereas the lower curve represents the results obtained with a simple jet without float-bowl. Both curves were obtained at 760-mm. (29.92-in.) pressure. As the temperature of the gasoline flowing into the carbureter is raised, the flow decreases, due to incipient vapor-lock. As soon as this occurs, boiling starts in the float-bowl, with resultant lowering of the vapor-locking tendency. As more heat is applied, the boiling becomes more violent, and the vent on the float-bowl is not large enough to permit sufficiently rapid removal of the vapor. Consequently, pressure is built up in the float-bowl and the flow through the jet increases. This would cause a very material enrichment of the mixture in an actual system. For the reasons pointed out, it was found to be impossible to get vapor lock in this carbureter under these conditions.

The carbureter used for the data in Fig. 7 was of the single-barrel type, and the results obtained are analogous to those shown in Fig. 6. In these two carbureters all jets were employed. In the third carbureter, the design was such that it was necessary to use only the main jet, and the vent from the float-bowl in this case was much larger than those on the other two carbureters. The results are shown in Fig 8 for the same fuel. In this case, there is no increase in the flow, but, due to the weathering in the float-bowl and a slight increase in pressure, the temperatures corresponding to various rates of flow are higher than were obtained with the simple jet but without float-bowl.

The curves in Fig. 8 indicate that, if the float-bowl vent is sufficiently large, the flow may decrease quite rapidly after the vapor-locking temperature is reached but may not decrease as rapidly as in a system without a float-bowl, due to weathering. To test this, a second series of experiments were made with the first carbureter but using a vent about ¼ in. in diameter. These results are shown in Fig. 9 for fuel 154 at 380, 570 and 760-mm. (14.96, 22.44 and 29.92-in.) pressure. The carbureter-flow curves are not very different from the curves without a float-bowl and indicate that the carbureter design can have marked effect on the vapor-locking tendency. For each carbureter, there is probably an optimum size of vent on the float-bowl which will prevent excessive leaning or enrichment of the mixture with a given fuel.

Fuel-Pump Experiments

In a previous report[7] data were presented on the vol-

TABLE 1—EFFECT OF VARIATIONS IN FUEL LINE ON FLOW

Variation	Pressure, Mm. Hg. 760	570	380	Temperature: Tank, Deg. Cent	Tank, Deg. Fahr.	Before Heater, Deg. Cent.	Before Heater, Deg. Fahr.	After Heater, Deg. Cent.	After Heater, Deg. Fahr.
	Gallons per Hour								
(a)	11.9	11.1	8.4	15	59	18	64	35	95
(b)	10.3	9.8	8.2	15	59	18	64	20	68
(c)	11.9	5.3	..	15	59	18	64	22	72
(d)	6.0	4.9	4.7	15	59	18	64	22	72
(e)	11.1	8.0	4.0	15	59	18	64	30	86
(f)	11.9	11.1	8.1	15	59	18	64	35	95
(g)	11.9	11.2	4.0	15	59	18	64	21	70

Computed Vapor-Locking Temperatures

Pressure, Mm. Hg.	Pressure, In. Hg.	Temperature, Deg. Cent.	Temperature, Deg. Fahr.
760	29.92	66	151
570	22.44	56	133
380	14.96	42	108

[7] See S.A.E. JOURNAL, August, 1930, p. 227.

umes of gasoline pumped at three pump-speeds, namely, 700, 1200 and 1770 r.p.m., and four heights of suction lift, namely, 0, 2, 4 and 6 ft. Two fuels, 184 and 194, were employed and with each speed and each height, measurements were made at the two pressures, 760 and 570 mm. (29.92 and 22.44 in.) of mercury, and also at 380 mm. (14.96 in.) in those cases where it was possible to lift the gasoline. Under each set of conditions the flow was measured at a series of temperatures. The limiting temperatures at which the flow of gasoline ceased were lower than those predicted from Equation (1) by amounts dependent upon the pump speed, the suction lift and the pressure. Further analysis of the data has shown that the deviations between the observed and computed vapor-locking temperatures under the same conditions of pumping were the same in the case of the two fuels. This makes it reasonable to assume that the deviations were characteristic of the pump and of the conditions of use, rather than of the fuels employed. It has been found possible to summarize the pump characteristics as a function of the conditions of use by means of the following relation:

$$\triangle = [218 - 75 \log P] + 3H\left[\frac{760 - P}{190}\right] + \left[\frac{3 + 0.5H}{6}\right]\left[\frac{760 - P}{190}\right] \times 10^{-2} S \qquad (3)$$

In this equation $\triangle$ is the difference between the observed and computed vapor-locking temperatures, corrected for the height of column of liquid being lifted; P is the atmospheric pressure on the gasoline in the tank, in millimeters; H is the height of suction lift by the pump, in feet; and S is the pump speed in revolutions per minute. Hence, given the conditions of operation of the pump, it is possible to compute with fair accuracy the lowering of the temperature below that given by Equation (1) at which vapor lock will occur on the suction side of the pump. Equation (3) should have a fairly general applicability, for the pump employed was of a type, C5, used very extensively in airplane fuel-systems.

Acknowledgment

This investigation was undertaken as part of a fundamental study of vapor lock in automotive fuel-systems. Its inauguration, limited to airplane systems, was made possible by a contribution from the Naturaline Co. of America and was at first conducted under the direction of the Research Committee of the Society of Automotive Engineers. In September, 1929, the supervision of this investigation was accepted by the Cooperative Fuel-Research Steering Committee and its scope was extended to include the fuel systems used in automobiles.

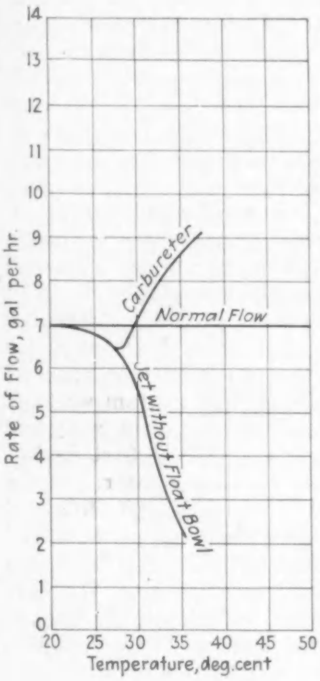


FIG. 6—FLOW THROUGH DOUBLE-BARREL CARBURETER *A*, USING ALL JETS

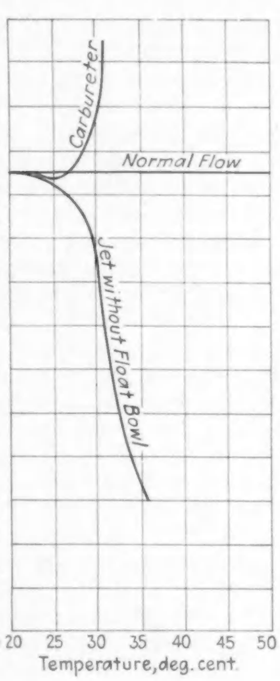


FIG. 7—FLOW THROUGH SINGLE-BARREL CARBURETER *B*, USING ALL JETS

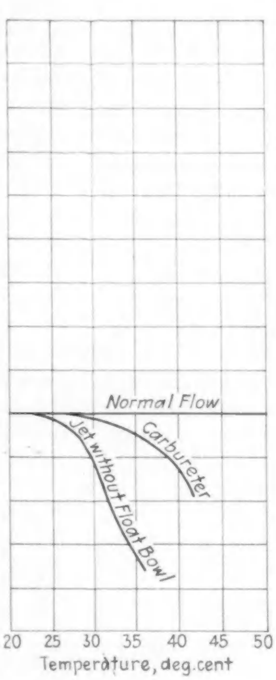


FIG. 8—FLOW THROUGH SINGLE-BARREL CARBURETER *C*, USING ONLY THE MAIN JET

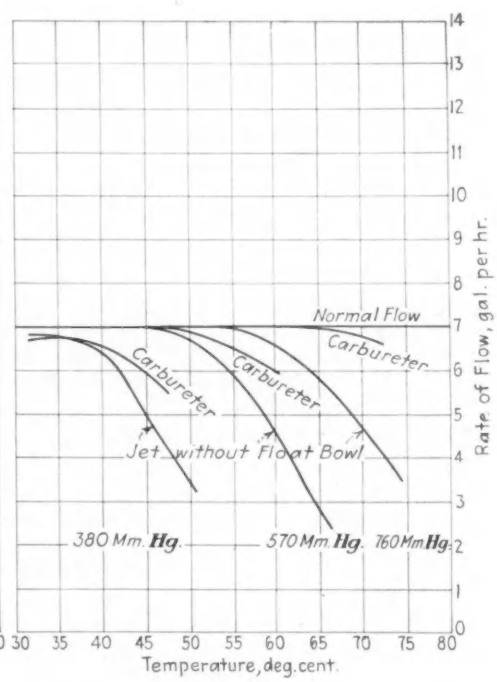


FIG. 9—FLOW THROUGH DOUBLE-BARREL CARBURETER *A*, USING LARGE VENT ON FLOAT-BOWL

Each Carbureter Was Used with the Standard Vent on the Float-Bowl, Except for Fig. 9. The Fuel Used Was a Grade-A Natural Gasoline. The Upper Curve in Each Chart Indicates Flow through the Carbureter and the Lower Curve Represents Flow through the Jet or Jets without Float Bowl. As the Temperature of the Gasoline Is Raised, Incipient Vapor-Locking Decreases the Flow, then Boiling Builds up Pressure in the Float Bowl, Which Tends To Increase the Flow. The Carbureter-Flow Curves in Fig 9 Are Not Very Different from Those in Fig. 8 and Indicate that Carbureter Design Can Have a Marked Effect on the Vapor-Locking Tendency

THE DISCUSSION

CHAIRMAN GEORGE W. LEWIS[8]:—The excellent work conducted by the Bureau of Standards on this particular problem is a guide to the failure of a number of gasoline systems in a number of types of airplane. The work that has been done, which has been reported on by the Army and Navy and the Department of Commerce, indicates that we now know where the trouble lies.

F. W. HECKERT[9]:—Does the type of pump have any effect on vapor-locking tendencies? The Army uses the C5 gear pump, and it occurs to me that it might be one that is failing in that respect.

O. C. BRIDGEMAN:—We investigated only the C5 type of fuel pump, which seems to be the one used almost exclusively on airplanes in this Country. If other pumps are used to any extent, we shall be glad to make some experiments with them.

MR. HECKERT:—We are experimenting with a pump now that may be adopted as an alternative standard. It is a rotary rigid-vane type known as the Romec. It has been run over continuously 3000 hr. on an endurance test and has increased in capacity about 8 gal. per hr. It has a much higher lift than the C5 gear pump, with very little drop in capacity over a wide range of discharge pressures. May not a pump of that type be better from the standpoint of delaying the tendency to vapor lock?

MR. BRIDGEMAN:—I think that is possible. There may be some other type of fuel pump that would perform better than the gear pump.

Wide Field for Research Open

WILLIAM G. WALL[10]:—This paper is certainly remarkably interesting. It explains a number of phenomena and shows considerable progress in ascertaining some of the troubles we have all experienced. In fact, I think that vapor lock probably has been the cause of many troubles that we have laid to other causes, not understanding exactly some of the fundamental facts in regard to vapor lock. I can see that there is an enormous field for research along this line, as so many different conditions enter into the possibility of having vapor lock of some description in the gasoline line.

The gasoline lines on airplane engines run up to certain temperatures, but on motor-vehicles the temperatures under the hood in very hot weather are even higher. Does Mr. Bridgeman think it would be of any advantage to insulate the gasoline lines? Although it has been tried, I do not know whether it is used normally on any particular makes of car.

One point that is of interest in regard to the flow from a small section to a large section is whether, when using a vacuum tank and sucking from one end of the line, that should be the small end or the large end. As evidently, with gravity flow, it makes a big difference in going from the smaller to the larger section, it is a question whether the difference in suction should not be reversed for vacuum feed. This subject has so many different phases that I think Mr. Bridgeman is doing a great work for all types of vehicle in conducting these experiments.

MR. BRIDGEMAN:—So far our work has been confined to airplane fuel-feed systems, but we are planning to investigate automobile fuel-feed systems. In the case of the vacuum-feed system, I should think it might be desirable to pass from the small to the large diameter to give free passage for bubbles of vapor.

As to insulating the fuel line against heat, it seems to me that something like that must be done if gasolines having a sufficiently low volatility are not obtainable. The temperature of the feed line under the engine hood cannot be reduced beyond a certain amount; even insulating it probably would not reduce the temperature more than several degrees. With insulation, a little more volatile fuel could be used than without the insulation.

A. L. BEALL[11]:—I think the vacuum tank must be considered as a secondary storage tank rather than an enlargement in the line. The fuel line to the vacuum tank would not be large enough so that there would be any expansion into it. The flow into the vacuum tank should be thought of as by gravity, the same as in the gravity-flow experiments Mr. Bridgeman has carried on. That has been our experience.

HARRY F. HUF[12]:—I have very definite evidence that, in some cases, insulating the gasoline lines has been of great help in eliminating vapor lock; in fact, I do not see how the builders can avoid insulating the line on some motor-vehicles that have a shutter on the front of the radiator to maintain the temperature under the hood at 180 deg. fahr. under all conditions. The heat must be kept out of the gasoline.

J. P. STEWART[13]:—Mr. Bridgeman showed a curve of flow with a fuel pump. I understood him to say that he had conducted some work with the pump submerged. Did the experimental results in fuel lock show higher temperatures than would be calculated from the A.S.T.M. distillation curve?

Another curve showed the effect of propane in reducing the vapor-lock temperature about 20 deg. cent. (36 deg. fahr.) below what would be assumed from the curve. What percentage of propane was in that gas?

Also, what recommendation would Mr. Bridgeman make to the manufacturers of tubing, connections and similar fittings on the constrictions that occur in lines from the probable slight enlargements and restrictions of the connections compared with the inside diameter of the tubing?

MR. BRIDGEMAN:—In our experiments with a submerged pump, the tube leading from the tank to the pump was of the same size as that used when the gasoline was being lifted by suction. I think that explains why the calculated results or values were still higher than those obtained even with the submerged pump. However, I have a feeling that if the inlet tube to the pump had been 3 or 4 in. in diameter, we probably would have obtained higher temperatures than those worked out from the vapor pressures, if we did not make corrections for hydrostatic heads; if we do make these

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[12] Jun. S.A.E.—Senior engineer, in charge of automotive laboratory, Atlantic Refining Co., Philadelphia.

[13] M.S.A.E.—Automotive research engineer, Vacuum Oil Co., Paulsboro, N. J.

corrections, I should expect the same temperatures.

Answering the second question, I do not know the exact propane content of that gasoline. I should judge that it was not much more than 1 per cent.

I have no definite information on the third question. I feel that it is very desirable to avoid any changes in cross-section of feed lines unless you use a special design. Mr. White, the co-author of this paper, has a feeling that a gravity-feed system of such a type could be designed which would be much better than those that are used at present.

An Ideal Gravity-Feed Fuel Line

H. S. WHITE:—The essential function of a fuel-feed line for gasoline engines is to deliver fuel to a carbureter at a rate that will keep the fuel in the carbureter float-bowl at a very nearly constant level, which is predetermined by the float adjustment. The two factors necessary to accomplish this in a gravity-feed system are a hydrostatic head of fuel sufficient to maintain the correct level in the carbureter bowl and a fuel passage large enough to transmit ample fuel for the given carbureter.

In a fuel-feed system having an adequate hydrostatic head and an amply large fuel line, the next important factor is the arrangement and design of the line such that it will not trap vapor or dissolved air, which may be given off by the fuel flowing in the line and hence reduce the effective hydrostatic head by an amount depending upon the length of vapor or air column formed in the line. An almost ideal line, from this standpoint, is one which has a vertical tank-outlet, with the line continuing vertical, or within 15 deg. of vertical, to a point on a level with the carbureter. This vertical line and outlet should be of uniform inside diameter, or the tank outlet should be larger than the connected line.

The ideal line is a long funnel-shaped vertical tank-outlet extending downward from the tank to a point on a level with the carbureter and tapering from a diameter at the tank equal to one-fourth or more of the vertical length, that is, 9-in. top diameter for 36-in. head, to a size corresponding to the line used from the bottom to the carbureter. This ideal line, or the one nearly ideal, which is more feasible commercially at present, will not trap continuous columns of gases even with very rapid bubble formation in the line; hence it should assure the maximum effective hydrostatic head for a given difference in level between the tank and the carbureter for all conditions of bubble formation in the lines.

From the bottom of the vertical line or the lower end of the long funnel-shaped tank-outlet, a line is run through the various valves and strainers and, with the necessary bends and elbows, to the carbureter float-bowl, for the fuel is assured the necessary hydrostatic pressure by the vertical line.

Lines departing from the ideal or nearly ideal installations such as lines slanting at a 45-deg. angle, having sharp elbows at the tank outlet or having a tank outlet smaller than the connected line, under flow conditions in which bubbles form in the line, trap gases in a continuous column, with the liquid fuel running along the sides of the tubing. When the continuous vapor column extends the length of the descending line in such cases, as it often does, the only effective hydrostatic pressure is that of the fuel in the tank. If the tank is shallow or nearly empty, the head is very small and the engine may slow or stop, due to the fuel pressure on the carbureter float-bowl being too small to provide sufficient fuel to keep the engine running.

Bubbles will form in the feed line with a slight rise in temperature if the gasoline is saturated, or nearly so, with air, or when there is a reduction in atmospheric pressure, as on mountain roads for motor-cars or, in the case of airplanes, under all flying conditions except low-altitude flying. Since these bubbles may form with any ordinary motor fuel and at any atmospheric temperature, their effect can be overcome only by fuel-line design and not by change in fuel. In this respect it differs from a true case of vapor lock, in which the fuel flow is reduced because the vapor formed is great enough to impede the flow of fuel. Interruption of flow in this case is dependent upon the fuel, since enough vapor is not liberated to hinder flow until the vapor pressure of the gas-free fuel becomes equal to the atmospheric pressure. In the case of gas traps, interruption of flow is not dependent upon the fuel to the same extent, because the trap collects the bubbles formed from dissolved air and gases, even though only small amounts of gases are liberated in comparison with the amount liberated in a true case of vapor lock.

JOHN O. EISINGER[14]:—Mr. Bridgeman's curves for the tube experiments showed rates of fuel flow at about 7 gal. per hr. for those different types of tube construction. Would he get any different results if the rate of fuel flow were 30 gal. per hr.; that is, would the rate of fuel flow have any effect on changing the prediction regarding vapor lock?

MR. BRIDGEMAN:—In the report on the preliminary work, which was given at the St. Louis Aeronautic Meeting, results were given for several different rates of flow up to, as I recall, 50 or 60 gal. per hr. There was no noticeable difference within the limits of our experimental work. We confined ourselves to the small rate of flow to economize on gasoline.

Fuel Pump Prevents Trouble at Altitude

LIEUT. C. A. ROSS[15]:—Some of the experiences encountered in trying to help Mr. Bridgeman in obtaining temperature-flow conditions in a Fokker C-7 transport airplane may be of interest. The Army has had gravity-feed fuel systems on all of its transports. Recently we undertook to get some of the fuel-temperature measurements with a Fokker C-7. This airplane was formerly a Fokker C-2, but was converted into a C-7 by replacing J-5 engines with J-6 engines. The same gravity system was used except that the fuel lines were enlarged from 1/2 up to 5/8 in. That, we thought, would give plenty of flow through the lines. We found in these experiments that when climbing above 10 000 ft. the outboard engines would stop. First, the left outboard engine would stop or continue to idle over, with no flow to the carbureter whatever for a period of possibly 2 min. Then, when that engine would pick up, the other outboard engine would act similarly. We found that the pipe to the left outboard engine had a bend that was considerably higher than the manifold which distributed the gasoline coming from the tanks to the side engines. The fuel-system arrangement is that each tank feeds separately to a manifold and the gasoline goes to

(Concluded on p. 458)

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In-Line *versus* Radial Aircraft Engines

Metropolitan Aeronautic Meeting Paper

By W. F. DAVIS[1]

FIGURES published at the end of 1929 indicate that nearly 280 airplane designs have been approved in the United States, as compared with less than 40 approved aircraft engines. Of course, far less than this number of either airplanes or engines are in actual production, but the ratio is indicative of the relative difficulties of producing satisfactory engine designs. The trained personnel, capital and time required for the development of a new aircraft engine are difficult to procure.

Fortunately, from the engineer's point of view, the 1929 depression in the aircraft business stopped the mad rush to put into production anything and everything in the way of an aircraft engine that would fulfill the minimum requirements for a license and turned the attention of the industry to a serious consideration of the pros and cons of various types of engine. The future of this great industry-to-be depends on what has been, or now is, only insofar as experience teaches us what should and will be. In other words, we must approach this consideration fully aware of what experience has taught us has or has not been accomplished but not deluded by statistics or figures derived from a period of the industry's history clearly dominated by commercial consideration and not engineering research or development. The fact that a larger number of a certain type of engine was produced in a given period than of any other engine merely proves that it was the most expedient thing to do and is far from proving that it was the best thing from any point of view. In fact, the present condition of the industry, which, by its very nature and importance, should be rapidly expanding in spite of a general depression in business, clearly shows that much remains to be done in aviation research and engineering before the industry will assume its rightly important position. A depression in the aircraft business probably would have occurred regardless of a general business depression last fall.

Reliability is the most important factor entering into the selection of an in-line or a radial engine.

Simplicity of design, which includes both the design and the number of the individual parts, tends to increase reliability.

Duplication of functions of crankcase and crankshaft parts results in decreased weight in a radial engine of a given cylinder displacement.

Improved visibility and reduced head-resistance favor the inverted in-line engine.

Ultimate cost of an aircraft engine includes first installation and service costs, all of which are influenced by the type of engine, and no actual figures that will permit a direct comparison to be made are available. Figures were submitted by one discusser tending to show that the in-line engine did not show such an advantage as automotive engineers had been led to believe.

Greater cooperation between aircraft and engine designers was stressed by another speaker.

The engine builders are only one, but an important, item of the factors responsible for the present condition of aviation in this Country. Being an important factor, then, they must help to place aviation where it belongs. Aviation, very distinctly, has something to sell, and it can ask a fair price for it. That something is speed. But it must sell speed with safety and comfort. Many problems in all phases of aviation must be solved to accomplish this result, but we can only be concerned here with the engine builders' contribution toward this end. Safety is paramount in this as in all other considerations, and safety demands engine reliability.

I do not intend to overlook the features of the Diesel-type aircraft engine, namely, decreased fire hazard and economy of operation due to the cheap heavy-oil fuel. I am greatly interested in the development of this type of engine and in the recent remarkable strides that have been made toward the solution of its problems. Unfortunately, time will not permit entering into a discussion of how the Diesel cycle affects various design features that might have a bearing on the type of engine, and therefore this paper is limited to a discussion of various features affecting the selection of in-line or radial-type gasoline engines.

Reliability the Most Important Factor

Reliability, then, is the first consideration in the selection of the type of engine. Of course, reliability can be proved only by exhaustive service testing and I do not feel that actual performance to date has proved the reliability of present engines to be adequate for the establishment of that public faith in aviation which is essential to the proper development of the industry. Therefore, we must inquire into the deficiencies of present designs and select, if possible, a type that will permit the elimination of those deficien-

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cies. The reliability of the eventual engine, of course, depends on much more than the selection of its type. It also depends on the simplicity and ruggedness of design, the selection and control of materials and process of manufacture and thorough and intelligent inspection and testing.

The inverted in-line air-cooled engine, due to the ease with which it can be full pressure-lubricated, including the entire valve-gear, and to the simplicity and rigidity of its block-type construction, presents features that cannot be duplicated in the radial-type engine. Every bearing of the engine, including the entire valve-gear, bearings, rollers and valve guides, can be readily pressure or flood oiled and cooled with a simple natural flow of oil to the valve-box cover as an oil sump. This cannot be satisfactorily or easily accomplished on a radial engine even with fully enclosed valve-gear and cannot be as easily or well accomplished on an upright in-line engine. The majority of troubles with a radial engine are in the valve-gear and are largely due to insufficient lubrication and cooling.

The rigid block-type construction of an in-line engine with overhead or underhead camshaft valve-gear practically precludes the possibility of a cylinder-head or cylinder-stud failure since the loads of each cylinder are transmitted to all the others through the cam-box casting, and the factor of safety is greatly increased. On a radial engine, each of the cylinders stands alone, and cylinder-head and stud failures are all too common. One indication of the relative rigidity of in-line and radial designs is the great amount of trouble that many radial engines have in preventing oil leaks from cylinder and casting joints caused largely by weaving and flexure of the parts under load. This condition does not exist in a rigid in-line design and the engine is consequently much cleaner and obviously less liable to failures from this source.

Simplified Design of In-Line Engines

Simplicity of design, of course, leads to increased reliability. This involves both the simplicity of design of individual parts and the number of parts in the engine. Any design, then, which reduces the number of parts to produce the desired result or eliminates complicated parts is to be desired. The in-line engine eliminates the complicated articulated-rod design of the radial and permits the use of simple connecting-rods, all of the same design, and allows ready provision of generous crankpin and main-bearing areas with low bearing-pressures, resulting in increased reliability.

The ease of manifolding an in-line engine for good distribution and volumetric efficiency permits the elimination of direct drive or geared-up blowers that have been found necessary on many radials to give satisfactory performance. The geared supercharger on an in-line engine is necessary only for special very high performance or for duplication of sea-level performance at altitude.

With an overhead or underhead camshaft and valve-gear, the in-line engine scores another point for simplicity and reliability in the elimination of many valve-gear parts and particularly in the elimination of valve-gear compensation for hot and cold clearance variations. The entire valve-gear moving integrally with the expansion and construction of the cylinders maintains very constant valve-gear clearance. The only variation comes in the expansion of the exhaust-valve stem and is readily allowed for in setting the clearances cold. This variation is in the right direction to decrease the overlap of the valves when cold and consequently is a benefit in starting and idling. An uncompensated radial valve-gear has many times the variation in hot and cold clearance and is in a direction to hamper the starting and idling performance if properly set for running clearance. A compensated radial valve-gear tends to correct this condition, but does so at the cost of complication and reduction of reliability.

Advantages of Air-Cooling

Irrespective of type of engine, the simplicity of air-cooling commends itself for reliability. Plumbing failures of liquid-cooled engines have always contributed a large percentage of engine troubles. However, the size of a satisfactory air-cooled cylinder is definitely limited by the heat-dissipating capacity. Someone has aptly said that the troubles of an air-cooled cylinder increase as the square of the bore. For reliability a maximum cylinder-size that is well within the limits of satisfactory cooling should be employed. Increased power then comes by increasing the number of cylinders, but a definite limit, due to permissible over-all dimension and complication of articulated-rod design and valve-gear, is set to the number of cylinders that can be employed in a radial design, nine seeming to be the practical limit. Eighteen-cylinder double-bank radial engines have been built, but they are extremely complicated and unsatisfactory in many respects. The limit of interchangeability for radial engines seems to be in the employment of the same cylinder assemblies on five, seven and nine-cylinder engines. Of course, numerous small parts and possibly rear-end sections can be made interchangeable also. The same interchangeabilities can be effected with the in-line engine, but this idea, which works so happily toward a great reduction in manufacturing cost, can be carried over a much wider power-range. A 6 or 12 and even a 24-cylinder in-line engine employing exactly the same cylinder and valve-gear banks and innumerable other interchangeable parts is a possibility.

The in-line air-cooled engine has been scored on the basis that to cool the cylinders satisfactorily and uniformly is complicated or difficult. Exhaustive tests of 4, 6 and 12-cylinder V in-line engines with simple scoop cowling properly designed have clearly demonstrated that this type of engine is very easy to cool with a variation of average cylinder-head temperature from cylinder to cylinder of less than 20 deg. fahr. This has also been thoroughly demonstrated in flight. Furthermore, a simple adjustment of baffles within the air scoop controls the individual cylinder-head temperature at will.

Another point not to be overlooked is the fact that under full-throttle conditions the variation of temperature from exhaust-side spark-plug to intake-side plug on any one cylinder does not vary more than 25 deg. fahr. This remarkable uniformity of cylinder-head temperature is due to the air-flow scheme employed in cooling this type of engine. The air is introduced in a sheet-aluminum scoop on the exhaust side of the engine, is then deflected and flows between and around the cylinders, passing out to the rear on the intake side. Thus the cylinders are effectively wrapped by the cooling air and receive maximum benefit from a relatively small volume of air. The uniformity of head temperature is due, then, to the coolest air acting upon the hot-

test part of the cylinder and also to the metal-to-metal joint between the cylinder-head and cam-box assisting in the rapid transfer of heat to a relatively large volume of metal. To produce these same desirable results in a radial air-cooled head requires individual cowling of each cylinder. This has been done, but is very much more complicated and expensive than the scoop of an in-line engine.

The radial engine can be made lighter in weight for a given cylinder displacement, due largely to the duplication of the crankcase and crankshaft parts. However, the restrictions placed upon its permissible maximum-speed due to the load of the heavy rotating connecting-rod assembly and the high inertia loads of the push-rod type valve-gear easily enable the in-line engine to equal or better the specific weight per horsepower by increased output at a high speed with no sacrifice of reliability. This is due to the low crankpin and main-bearing loads of the in-line engine and to the low inertia and valve-spring loads of the overhead-camshaft type valve-gear. Higher speed is often incorrectly associated with loss of reliability. A moment's consideration of the increase of speeds in all walks of life and all types of machinery with no loss of safety or reliability will convince anyone that it is merely a matter of the selection and refinement of a suitable mechanism for operation at the higher speed, as illustrated in present automobile engines.

Much stress is laid on the increased efficiency of slow-speed propellers. This efficiency is as much a function of airplane speed and characteristics as engine horsepower and speed and to lay down any definite rules governing it is difficult. However, the smooth performance of a six-in-line, or an engine in multiples of six, makes it much better suited to reduction gearing than a radial engine and offers a proved solution.

Comfort and Visibility Important

Comfort is increasingly important in aviation. This is primarily an airplane problem, but the type of engine has a distinct bearing on it. The day is rapidly approaching when we will be no more content to fly around behind a roaring, clattering, half-exposed engine than we would be willing to ride around with our automobile hood off and muffler disconnected. We must then have a completely enclosed, clean and quiet engine. The in-line inverted engine with completely enclosed valve-gear is easy to enclose completely and is decidedly cleaner and mechanically quieter than a radial engine. That aircraft engines will be really quiet is not expected for some time and we will probably always have propeller noise with us. However, exhaust manifolding and muffling can be easily applied to this type of engine without the complication of exhaust manifolding of a radial. Even without manifolding the exhaust location is well suited to noise and dirt reduction, being well below the pilot and passenger positions.

Improved visibility is an obvious feature of the inverted in-line engine. This is important only in nose installations, but there it provides excellent top and side visibility which is obtained at once with a higher propeller centerline and its attendant lower landing-gear than is possible with either radial or upright in-line engine.

Reduction of head resistance is also a point in favor of the in-line engine. This is particularly important in all other than nose installations, for there the full frontal-area of the engine becomes parasite resistance. In nose installations, the fuselage dimensions often become the limiting factor, and only the large radials are objectionable in this respect.

In the case of wing installation of engines, the inverted in-line type offers a very obvious advantage in that about 80 per cent of its projected frontal-area is below the propeller centerline, thus leaving the flow of air to the upper wing-surface entirely undisturbed.

Comparison of Costs

From the point of view of the consumer, the ultimate cost of an aircraft engine consists of its first installation and service costs. The type of engine has a bearing on all these costs. Unfortunately, no figures are available for direct comparison from actual records. Such a comparison must be made for several sizes of engine of each type, of equal quality, and based on actual manufacturing costs in like quantities and on actual service records over a period of time.

The cost of tooling for a radial engine is somewhat less than for an in-line engine. In limited quantities, standard machine-tools are somewhat more suited to machining radial parts than in-line engine-parts. Hence, in limited quantities the manufacturing cost of a radial engine should be somewhat lower. In quantity production, however, these factors become insignificant and the specialized high-production machinery that has been developed for the automotive industry and that is readily adaptable to in-line aircraft-engine production should offset this difference in manufacturing cost.

The usual mounting of an in-line engine is slightly more expensive than a radial mount. However, the difference is very little between the total installation-cost of a completely cowled radial and a fully enclosed in-line engine.

In service cost and life the high-grade, full-lubricated, in-line engine will greatly surpass the radial. The engine can be a completely self-oiled unit requiring no oil-can or grease-gun service. The flood-oiled valve-gear will require practically no attention and will show no perceptible wear. The low bearing-pressures will guarantee long life, as will the low piston side-thrust that is possible with the in-line engine due to the low maximum-angularity of the plain connecting-rod used as contrasted with the necessarily greater angularity of the articulated rod of a radial engine. These features mean that the routine attention given to an engine of this type would be much less than that required for a radial and that the periods between overhauls would be greatly increased.

In limited production the first cost of an in-line, lubricated engine may be expected to be somewhat higher than an equivalent radial engine. In quantity production, the cost of an equivalent installation would be about the same and the service cost would be much less.

My remarks should not be construed to imply that further development of the radial-type engine may not eliminate some or all of its problems nor that the in-line engine will not fall heir to its share of trouble. A careful study of the subject, however, has convinced me that the inherent features of this type engine offer a ready solution of some of the radial's most difficult problems, and actual test has shown me that the difficulties commonly feared in the development of the in-line engine have been readily overcome.

THE DISCUSSION

GLENN D. ANGLE[2]:—Comparing a group of representative types of commercial radial and in-line engines on the basis of weight per cubic-inch displacement, I find, in comparing the four-cylinder in-line and five-cylinder radial engines, which of course gives a distinct advantage to the in-line because it has one less cylinder, that the radial engine has a greater displacement per pound of weight by 10.6 per cent. Comparing a six-cylinder in-line and a six-cylinder radial, the advantage of the latter is 21.7 per cent, and comparing the six-cylinder in-line with the seven-cylinder radial, the advantage is with the radial by 21.2 per cent. Taking all of these engines, the average shows that the radial engine has an advantage of 17.3 per cent. That figure in itself I believe is a fair average because I have not selected any of these engines on the basis of low weight. In fact I have included one or two radials which, if they were left out of these figures, would make them appear much higher.

The question of frontal area has been to my mind the only argument for the in-line type of engine. I was rather curious to see how it actually compared, so I used the same group of engines, on which I have just compared the weight per cubic-inch displacement, in studying their frontal area.

In the first place, I took the area of a circle enclosing a radial and the area of a rectangle enclosing an in-line engine and compared them, making figures on the basis of cubic-inch displacement per square foot of over-all frontal area. The comparison between the five-cylinder radials and the four-cylinder in-lines shows the radials have 45.4 per cent less cubic-inch displacement per square foot of frontal area than the in-line. Comparing the six-cylinder in-line with the seven-cylinder radial, the radial shows 39.8 per cent less displacement, and comparing a six-cylinder in-line and a six-cylinder radial, the latter has 46.7 per cent less displacement. The average of all these figures is 40.4 per cent. That, of course, shows a considerable advantage for the in-line engine on the basis of cubic-inch displacement per square foot of frontal area, but we must keep in mind the fact that this circle completely enclosed the radial engine and did not take into account the space between the cylinders nor the cowling necessary to enclose an in-line engine.

Taking the actual frontal area of these same engines and comparing the five-cylinder radials with the four-cylinder in-lines, the radials showed 36.8 per cent less cubic-inch displacement per square foot of frontal area. Comparing the six-cylinder in-line with the seven-cylinder radials, the radials showed 45 per cent less displacement and between the six-cylinder radial and the six-cylinder in-line, the radial has 39.2 per cent less displacement. The average of all the radials and in-lines showed that the radials had 37.2 per cent less cubic-inch displacement per square foot of frontal area. In this particular comparison, I wish to point out that some of the radials included are very bad from this point of view.

To show what is really possible, I made a comparison of the best radial and the best in-line in this group. In a comparison of a radial and an in-line of the same displacement, the radial engine only showed 16 per cent less cubic-inch displacement per square foot of frontal area, which is a very small disadvantage.

I also made another comparison of these engines on the basis of length. The average shows that the radial engine is 68 per cent better than an in-line engine on the basis of cubic-inch displacement per inch of length.

Then to carry this investigation even farther, I made a comparison of the cubic-inch displacement of these engines as against their cubic-foot over-all displacement; that is, the rectangle that enclosed the in-line multipled by its over-all length and the area of the circle enclosing the radial engine multiplied it by its length. In this comparison, of course, considerable waste space around the radial engine is included. In the comparison between the five-cylinder radial and the four-cylinder in-line, the in-line engine showed 17.9 per cent more cubic-inch displacement per cubic foot of over-all displacement. Comparing the seven-cylinder radial with the six-cylinder in-line, the radial engine showed 21.1 per cent more cubic-inch displacement. The six-cylinder in-line and the six-cylinder radial comparison showed an advantage with the in-line of only 3 per cent. Taking all of these, the average showed 3.2 per cent in favor of the radial engine, and, as I said before, some of the radials in this group are very poor from the standpoint of these comparisons. As a matter of interest, I selected the best radial engine from this group on the basis of its over-all dimensions and compared it with the best in-line, and this showed the radial engine to have 37.6 per cent more cubic-inch displacement per cubic-foot over-all displacement.

In measuring these areas no attention has been paid to the usual cowling. In the cowling of a radial engine, very little of the area not measured in these figures would be covered up, while in the in-line engine, the cowling would entirely surround the area measured and increase it by several per cent. If we had those figures, they would probably change this comparison to a point where the in-line engine would not show such an advantage as we are led to believe. Just as many cubic feet of air per minute per horsepower are required to cool an in-line engine as a radial and I believe the resistance of cowling itself is practically the same. With the advent of the N.A.C.A. type of cowling we have showed that we can reduce the drag considerably.

A very interesting thing, which I learned just the other day, is that on a particular radial engine of very small diameter, smaller in fact than the diameter of the fuselage, this company tried an N.A.C.A. cowling and improved the speed only 2 m.p.h., the reason being that the cowling back of the engine was so nicely streamlined that it pretty well straightened out the disturbed air-currents coming off the cylinders. This showed that if a radial engine is designed with head resistance in mind, it certainly is not as bad as we are led to believe. We have a number of radial engines today which apparently were not designed with that idea in mind.

W. F. DAVIS:—We have made certain comparisons between certain sized radial engines and in-line engines of equal horsepower and in every instance the frontal area or resistance, both projected and parasitic, has been much less in favor of the in-line engine. I have never gone into the detailed figures for comparison on

[2] Vice-president, LeBlond Aircraft Engine Corp., Cincinnati.

the basis of cubic inches of displacement per square foot of frontal area and all that, but even with a smoothly cowled in-line engine the air resistance to the airplane containing the engine or on the nose of the ship should be much less than it is with a radial engine of equal horsepower. Unquestionably the in-line engine is longer than the radial, but that does not seem to have any effect on maneuverability of airplanes in which the engines are placed. We have made a considerable number of test flights in different types of airplane with these engines, just to ascertain that fact.

A. A. GASSNER[3]:—Mr. Davis has compared the theoretical in-line engine, of which only apparently drawings exist or samples are built in the test rooms, with radial engines that have been operated. Many things in favor of the in-line engine have not been mentioned. One is the possibility of cooling cylinders with fins running up and down the cylinders, as used on Franklin air-cooled automobile engines. On the radial engine we get considerable air-flow at places where we do not need it, and then we try with cowlings and baffles and similar devices to take care of the situation, but the turbulence that exists is increased by all these baffles. The N.A.C.A. cowling helps in giving us speed but it makes the engine inaccessible. We have found that the Townend ring coupling, which was developed in England, gives practically the same results, as far as increasing speed is concerned, as N.A.C.A. cowling but leaves the engine accessible for maintenance purposes.

Another effect of radial engines is that turbulence exists on multi-engine aircraft between the engine and the wing, which has not been very well considered in the past, and we found that by moving the engines far forward of the wing or at a considerable distance below the wing, we made a considerable gain in speed, eliminating some of the turbulence between engines and wings. Not only does the frontal area give trouble by increasing the drag. The turbulence does the same. If we give these vortices a chance to calm down behind the engine and put the wing farther behind the engine, the interference is less. These vortices on multi-engine airplanes extend in fact all the way back to the tail and give some trouble there which is sometimes hard to overcome and which requires considerable study.

The radial engine is very easy to mount. The structure is simple, everything is accessible, but we cannot always have our engine hanging all over the place. Airplane designers were forced to put the engine out front at first because they were air-cooled. The moment we want to put an engine inside the wing, the radial air-cooled engine is practically out of the question. Nobody yet was able to develop a cowling for radial engines inside a housing, and this is then a great factor in favor of the in-line engine, especially the inverted in-line engine.

MR. DAVIS:—My views are not theoretical, as we have built six in-line engines at Farmingdale. In a previous connection I built other in-line air-cooled engines. Allison has built to my knowledge at least 12 inverted Liberty air-cooled engines, from which the data that we have used in building these other engines have been collected.

Undoubtedly the in-line engines need less air for cooling due to the utilization of practically all the air on the cylinder barrel for that purpose. The air surrounds the cylinder barrel almost completely in an in-line air-cooled engine, which does not occur in most radial installations unless the air is forced around the cylinder by baffling.

T. E. TILLINGHAST[4]:—We will all have to concede that the in-line type of engine may have a certain advantage over the radial type; namely, that of a well-lubricated valve-gear, although Mr. Davis very generously admitted that some of the trouble in this respect on radial engines could be eliminated, and I think that all radial-engine builders are at present engaged in modifications of present designs that they hope will take care of this condition. As far as the speed of the two types is concerned, the in-line engine unquestionably has less frontal area. However, as Mr. Gassner has just pointed out, the frontal area is not the whole story. We know that with the Townend ring, on a single-engine airplane at any rate, we can obtain just as good performance as a plane with an in-line engine. As a matter of fact, to date we have obtained a little better performance per horsepower with the radial type of engine than with any in-line type, wing radiators excepted. The whole question would seem to be whether or not the easier maintenance of the valve-gear on the in-line type of engine will be worth the increased weight over that of the radial type.

Cooperation between Aircraft and Engine Designers Urged

R. W. A. BREWER[5]:—I want to endorse very strongly what Mr. Gassner has said. In the past the separation of thought and idea between the aircraft designer and the engine designer has been too great and if we are really going to get anywhere, we must have very much closer cooperation.

Mr. Gassner has told us that the engine as an engine does not matter so much as the general scheme of an engine mounted in an airplane. We discussed this also at Langley Field and I hope that we will get some further figures from that source. They have given us some very good reports so far on the effect of various locations of the radial engine relative to the front edge of the wing and the position of the propeller relative to the edge of the wing and interference effects. That has been an investigation of conditions as we now find them. What we must do is to design so that we do not get those conditions, and a very considerable modification is coming, both of engine design and engine mounting, and by that cooperation between engine designer and aircraft designer, rather than in the discussion as to the relative merits of two particular types of engine, we are really going to get some improvement. We must consider the engine as it is mounted in the airplane, which not only includes interference, cowling and turbulence effect but also noise and vibration. These two latter are extremely serious at present, because no matter how good an engine is, if it is noisy and if it vibrates, people will not have it.

When Mr. Angle was talking about some figures, of course they were very interesting, but he could have told us something very much more interesting, and I hope he will be able to, concerning engine problems with regard to crankshaft vibration, inertia, torque and crankshaft whip and periodic speeds, which are asso-

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[4] M.S.A.E.—Executive engineer, Pratt & Whitney Aircraft Co., Hartford, Conn.

[5] M.S.A.E.—Consulting engineer, Aircraft Engine & Accessory Development Corp., Jenkintown, Pa.

ciated with both of these two particular types of engine.

If we get a long engine, we all know that we encounter serious crankshaft trouble, and that is particularly indicated in the big Beardmore engines that were built on the other side. Of course those shafts are longer than we are talking about now, but only by thinking in extremes can we really get down to facts. The engines gave all sorts of crankshaft trouble, and their horsepower was only about 75 per cent of the designed horsepower.

I hope that the two types of engine can be considered with regard to some of these engineering problems that really matter very seriously.

JOHN M. ALLISON, JR.[6]:—The most interesting remarks to me were those concerning the relative drags of the radial and in-line engines. I think, from the data we have, that the radial engine, when mounted in a well-designed nacelle of a multi-engine airplane and equipped with N.A.C.A. or Townend ring-type cowling, has but little more drag than the similarly installed in-line engine with its most effective cowling. National Advisory Committee for Aeronautics Report No. 314 shows that with a small body like a nacelle back of the radial engine, instead of a fuselage, the drag of the completely cowled engine is less than one-fourth that of the engine alone, uncowled, at 100 m.p.h. Moreover, in the case of engines installed out on the wings, the question of visibility is not an important factor, so that the radial engine is not at a disadvantage, as it admittedly is in fuselage installations, particularly of the larger sizes.

E. G. KINGSTON[7]:—My remarks will deal more particularly with the necessity for proper lubrication of the valve gear. Some time last fall, the company with which I am connected learned of considerable trouble being experienced by a certain aircraft-engine manufacturer through the breakdown of anti-friction bearings used in the valve gear of his engine. I stated to our chief engineer that I thought the trouble was not with the bearings, as claimed, and suggested that we procure enough engine parts to conduct a test. This engine, by the way, was a radial, and hence the lubrication of its valve gear could not be as easily taken care of as is possible in an in-line design, as Mr. Davis has pointed out. In the tests that we ran on this engine we were not able to find that the bearings were breaking down. We did find, however, that lack of lubrication had caused other parts to break down and ruin the bearings through the particles of metal from these parts getting into the bearings. When we asked for more parts to continue the test further, we found that the engine builder, having benefitted by the results of such tests, had made changes so that the bearings, which were formerly lasting only 13, 14 and 15 hr., were going over 1200 at the last reports.

HOWARD HUNTINGTON[8]:—Very little attention is being paid to an ever-growing need in aircraft design, nice appearance, looks. We must appeal to the eye in aircraft design. If the straight-in-line engine gives promise of a more rakish appearance, a long hood—I use the word "hood" because everyone using automotive transportation is accustomed to this term—if it lends itself to better appearance, better appeal to the eye, that will count in its favor very heavily. The prime essential, as we have heard several times in this session, is reliability, the second is efficiency, and the third, also a very important essential, is the appearance of the airplane when the engine is mounted in it, rather than attached to it. Let us bear in mind in designing either a straight-in-line or a radial engine, that we must make it fit into the scheme of things in the complete airplane design.

The new Huntington Governor monoplane is equipped with a radial engine, although this design, which I have been working on for some two years, was originally intended for a straight-in-line inverted engine. As two such engines were being developed at the time, I thought we would have at least one before my design was finished, but after tests of various engines, I found no straight-in-line inverted engine suitable for the small type of airplane that I am building.

Apparently we work faster in aircraft development than you do in the engine field, as when we were ready, we could find no trace of the inverted in-line engine, which seemed to have vanished into thin air. Therefore, of necessity, we adopted a radial engine. Out of fairness to the radial-engine advocates, I must say that if that type remains as reliable and as efficient and as light in weight as it is today in comparison with the straight-in-line engine, we will continue to use the radial engine.

We are now looking for a comparison within the next few months between the radial engine, which has proved so successful in my present ship, and the straight-in-line inverted engine in one of the five new Huntington Governors which we will build. Then we will have more exact data as to the advantages and disadvantages of each type in an otherwise similar airplane.

E. S. HALL[9]:—So far but two types of engine have been mentioned, the radial and the in-line. When we try to make a radial engine of more than 600 hp., we encounter difficulties, and when we try to make an in-line engine with 24 cylinders in a straight line, as was mentioned, we also have difficulties. We should, I think, start thinking about a third type, the round engine, in which the cylinders are parallel to and equidistant from the main shaft. The projectile shape of such an engine fits the fuselage perfectly, and for the larger powerplants multi-cylinder engines with almost any number of cylinders can be built in a very compact and rugged construction. One practical mechanism for such an engine is the Michell oil-wedge mechanism that has been developed in Australia. Through the last decade operation has shown that this is a practical engine-mechanism offering advantages that cannot be approached by the crankshaft and connecting-rod.

Ethylene-Glycol Cooling

D. B. WILLIAMS[10]:—Ethylene-glycol has a flashpoint by the open-cup method of 116 deg. cent. (240.8 deg. fahr.) and 122 deg. cent. (251.6 deg. fahr.) by the closed cup. It has an apparent ignition-temperature in the air of 416 deg. cent. (780.8 deg. fahr.). This should cause no apprehension, however, since glycol is being used in many airplanes at present and, although

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[7] A.S.A.E.—Consulting aeronautical engineer, New Departure Mfg. Co. division, General Motors Corp., Bristol, Conn.

[8] President, Huntington Aircraft Corp., Stratford, Conn.

[9] Automotive engineer, Michell Crankless Engines Corp., New York City.

[10] Automotive department, Carbide & Carbon Chemicals Corp., New York City.

several of them have cracked up, to the best of our knowledge and that of the people who operated the planes the glycol did not catch fire. Although the material will flash, it is very difficult to ignite and is not considered a problem by the companies that are adopting it commercially.

This naturally brings up the question of leakage when the airplane is in the air, which is one of the most important problems in connection with the design of an ethylene-glycol-cooled engine. The efforts of the engineers who have designed these engines have been directed along the lines of eliminating leakage entirely, and the work has progressed to the point where we do not feel that leakage is an important factor. If leakage is eliminated then the possibility of any trouble in the air is also eliminated.

The oil temperatures in a glycol-cooled engine will run about 22 to 30 deg. fahr. higher than the oil temperature in a water-cooled engine and engineers who have investigated very thoroughly have found that coolers are not necessary for certain engines when using a 120 viscosity oil, thus eliminating 0.05 lb. per hp. The question of lubrication with a 20 or 30 deg. fahr. higher temperature in the crankcase can be solved by the use of the proper lubricant.

In connection with the reduction in weight, Gerhard Frank, in a paper[11] presented at the 1929 Cleveland Aeronautic Meeting, said that reductions in radiator surface of about 70 or 75 per cent and in the volume of the coolant used of about 30 per cent are possible. I do not know just how that agrees with Mr. Mead's paper at this meeting. I believe he said that the cooling system for an ethylene-glycol engine would be 0.4 lb. per hp. in comparison with 0.6 lb. per hp. in the case of a water-cooled engine[12]. The pilots who have operated these airplanes are unanimous in saying that a glycol-cooled plane will outfly, out-dive and out-maneuver a water-cooled plane.

KENNETH S. CULLOM[13]:—Does not the use of ethylene-glycol necessitate redesigning the engine-cooling system as regards the fit between the cylinder and crankcase, to prevent leakage, or could any water-cooled engine be considered adaptable for ethylene glycol?

MR. WILLIAMS:—Water-cooled engines have been adapted to, and successfully operated with, glycol without any changes other than those that could be effected in valve and piston-ring clearances by changing the rings or resetting the valve tappets. I believe that we would be perfectly willing to admit that an engine which is designed primarily to use glycol can operate more successfully than a water-cooled engine to which glycol is applied, but I am not prepared to say that a water-cooled engine cannot be operated with glycol without redesigning.

MR. CULLOM:—I remember an instance where a Curtiss D-12 was put through a regular endurance-test at possibly 90 per cent of full power, using ethylene-glycol instead of water. One trouble, which I remember distinctly, was that when the test ended we noticed ethylene-glycol was leaking out of the exhaust ports and we could also notice it definitely in the lubricant which was sweet and colored from the coolant.

[11] See S.A.E. JOURNAL, October, 1929, p. 339.

[12] See S.A.E. JOURNAL, August, 1930, p. 145.

[13] Production engineer, E. W. Bliss Co., Brooklyn, N. Y.

[14] M.S.A.E.—Chief airplane engineer, Wright Aeronautical Corp., Paterson, N. J.

MR. WILLIAMS:—Of course mechanical problems arise in connection with this application. Obviously that would be the case when operating with an outlet temperature of 300 to 350 deg. fahr. Conditions different than when we are using water as a coolant would be encountered but we do not feel that these mechanical troubles are beyond solution and they have been solved to a great extent.

Carbureter Location Important

G. G. EMERSON[14]:—Mr. Davis has made some very strong points in favor of the in-line engine, but he has confined himself almost solely to the inverted in-line engine. In a vertical in-line engine of the upright type the carbureter is possibly some 20 in. higher than it will be in the same radial installation. This means that to get a gravity head on the carbureter we must either put all the gasoline in the wings or use a pump system, and Navy Department figures compiled over a period of some eight years show that the number of forced landings due to fuel-system failures was something like 52 per cent of all powerplant failures, which is rather a serious thing. Without question the straight gravity-system is the most desirable and is much easier to have on a radial than on a vertical in-line engine.

The second point I want to bring out is that in considering the Townend ring we have confined ourselves to a consideration of the removal of turbulences of the engine. We actually do get a forward or negative drag, shall we call it, from the Townend ring, which is not entirely due to the removal of the disturbances, but also an actual aerodynamic force that pulls that ring forward. That is, if we do not attach this ring tightly enough, it will drag right into the propeller. This has happened before and for that reason the Townend ring is more adaptable to the radial than it is to a rectangular in-line engine. With a radial with its large outside diameter, we can get a much larger ring on it and get much more of that aerodynamic effect upon it. This is an advantage that we will have still to consider in radial engines, because the Townend ring is still in the experimental stage, but I think eventually it will develop into a permanent standard installation on all radial engines, and, in general, as we have heard, it increases the speed of an airplane from 5 to 8 m.p.h. Wind-tunnel tests have shown that with a Townend ring around a circular disc, the drag of that combination was reduced to something like 48 per cent of the original drag of the disc alone, which gives some idea of just what that ring does. It actually drags forward, as I said.

The third point I wanted to take up was the question of in-line engines in general as against the radial type, principally from an aerodynamic standpoint and from consideration of controllability of the airplane and maneuverability. That the plane rotates about three axes through the center of gravity is well known and to control it we must have tail surfaces that will displace it around the vertical axis. When we put an in-line engine in front of that airplane, we immediately increase its inertia about that axis and in many cases we find that an airplane is much more unsafe aerodynamically than the same airplane with a radial engine in it and that it immediately requires a much larger control surface at the tail to bring it out of a spin.

MR. DAVIS:—Although placing the carbureters low enough on the upright in-line engine might be somewhat difficult, on an inverted in-line engine we can put

the carbureter anywhere we desire and get it lower than on the radial engine. One other advantage that the in-line inverted engine has over the radial is the fact that the pressure oil-pump is located considerably higher than on the majority of radials. Therefore we are not annoyed by having oil leak into the crankcase.

A. C. HEWITT[15]:—One form of engine has not been discussed here, and that is the horizontal opposed engine. That offers some advantages which Mr. Davis enumerated in the in-line engine, and I think it has a possibility of offering some advantages from an installation point of view. For instance, on a thick-winged monoplane, a horizontal opposed engine could be placed inside the wing, provided we could clear the forward wing-spar with the propeller shaft. By placing the exhaust outlet on the bottom so that we could get sufficient cooling, we would be able to get some lift on that type of engine which is rather difficult to do with any type that we now have.

MR. BREWER:—Carbureter location which Mr. Emerson mentioned is a very controversial matter indeed.

MR. EMERSON:—I still think it has something to do with the fin area. We cannot neglect that entirely.

ADOLPH MOSES[16]:—Other things being equal, an airplane powered by a radial engine is likely to be more maneuverable than one powered by an in-line engine, because the center of gravity of either engine will have to be placed in about the same position to properly balance the plane, but the radial will have a smaller moment of inertia because it is more compact. Inasmuch as an engine is rarely, if ever, entirely exposed by itself, the relative resistance of either type alone is of little importance. Rather they should be considered as applied to an airplane. In this connection, each has advantages depending on how it is installed. Approximately the same results, as Mr. Tillinghast mentioned, have been obtained with either the radial or the in-line engine of about the same power. This proves that the projected area of the engine alone is of little importance, for although the projected area of the engines varied widely, the performance of the airplanes, when the engines were properly installed, was about equal. At present, because of the small demand for engines, the radial has the advantage of low initial-cost because in small lots it is cheaper than the in-line engine.

MR. DAVIS:—The long in-line engine possesses a greater safety factor since with the load distributed all over the length of the engine, an airplane with that type of installation is less apt to go into a tight spin than one with a radial engine.

[15] M.S.A.E.—Engineer, Wright Aeronautical Corp., Paterson, N. J.

[16] M.S.A.E.—Chief engineer, Chevron Motor Corp., New York City.

The Effect of Airplane Fuel-Line Design on Vapor Lock

(Concluded from p. 450)

the three engines from the manifold, with three individual valves, one for each engine. When we dropped the line to eliminate the hump, we had trouble first with the right engine, and when we were up to 10,000 or 12,000-ft. altitude, we would have trouble with both outboard engines.

Most of this work was done in fairly cool weather, this making it very questionable whether the trouble was caused by vapor lock. When we analyzed the difficulty, we found that we had a 48-in. head from the tank to the carbureter under the best conditions; that is, with a full tank. The Stromberg Carbureter Co. specifies that the pressure of fuel should be 3 lb. per sq. in. at the carbureter for that particular design. A single-float carbureter was used on the J-6 Whirlwind engine, whereas on the J-5 Whirlwind engine a double-float carbureter is used. The 48-in. head gave a maximum of about 1.5-lb. pressure on the float needle-valve of the carbureter that should have 3-lb. pressure. We believed that we might not have this same trouble with the C-7A Fokker of more recent design, this airplane having more carefully laid out fuel lines, but when we climbed the C-7A to 12,000 or 14,000-ft. altitude, we encountered exactly the same difficulty. For that reason we have put fuel pumps on all the J-6 Fokkers, which entirely eliminated the trouble.

During the investigation the fuel pressures were measured by means of a mercury manometer at the carbureter inlet and we found that at the time the engine failed at great altitude we were getting practically no fuel pressure at the carbureter. According to the Stromberg specifications, we should have about 3-lb. pressure, yet the engines would still run until the pressure dropped nearly to zero. We regarded this situation as an entirely unsafe condition for great-altitude flying. Flying the ship with the gravity-feed system to California was contemplated, but that idea was abandoned until the fuel system with pumps was installed. I recently flew the C-7 Fokker equipped with pumps to Sacramento and had no trouble whatever at any altitude. At times I climbed as high as 15,000 or 16,000 ft. to get over bad storms in the Western mountains, and positive flow was maintained all the time. We calculated that an 8-ft. gravity head from the level of the gasoline in the tank to the carbureter would be required to give 3-lb. pressure at the carbureter, and an 8-ft. head cannot be obtained in any airplane having a gravity-feed system.

Automotive Diesel Engines

By C. G. A. ROSEN[1]

Northern California Section Paper

THE title of this paper is a bold suggestion of an established mechanical Elysium, free from travail or grief. Fortunately for the requirements of material for this paper, the latter condition is not true, and I am privileged to devote a little time to discussion of the problems, not so much of design but of fundamental character, that are crystallized in the solution of combustion control. These problems, possibly, may be adequately solved only by encroaching upon the hinterland of applied science.

Credit must be given for the advances that have been made to date in the development of the high-speed Diesel engine. The concentrated efforts of patient investigators and the determined force of courageous manufacturers have made possible the revelation of the problems involved and have influenced the clarification of divergent opinions to the point where present development is acquiring a directive course of action. Undoubtedly, in the very near future, some cooperative group of researchers will so coordinate the heterogeneous efforts of all developments and employ the forces at their disposal to arrive at the goal of achievement. Or, perchance, as so often happens in experimental work, a lone experimenter may stumble upon a new avenue of thought that shall lead to the desired results.

At any rate, the present oil engine is not ready to be substituted on a commercial basis for the gasoline engine in automotive work. In the term automotive Diesel engines I shall include all high-compression oil engines employed for propelling automobiles, trucks and tractors; and, dealing with the problems involved, this entire field will be given consideration. The service demands differ in each classification but, if flexible combustion-control can be obtained in small engine-bores, the application can be made indiscriminately to all classes of high-speed service.

True enough, we read accounts of automotive Diesel engines appearing on the streets of Europe. Some 500 oil-engine trucks and motor-cars are reported to be in operation on the Continent and also several hundred working tractors consuming light fuel-oils in surface-ignition engines. In our own Country we are informed of isolated instances of oil engines performing automotive duty. Most of these are of the experimental variety, while others are being tried under consignment privileges. Why, then, the apparent apathy to a broader acceptance of the new prime mover? A number of reasons may be gleaned from the following analysis of economic service-demands:

Problem of Suitability of Fuels

(1) The present demand for automotive oil-engines is largely localized in districts where economically available fuels are not readily combustible in carbureter engines. The engine builder is, therefore, called upon to produce engines that will burn a variety of fuels to give satisfactory results.

Many of the European automotive Diesels operate satisfactorily on carefully selected fuels but are limited in their ability to consume other fuels. Similar conditions exist in this Country. The American Society of Mechanical Engineers is endeavoring to standardize Diesel-engine fuels. It has advanced specifications for two grades of fuel, one for slow-speed and the other for high-speed Diesel engines. The oil companies have expressed their willingness to cooperate in this work provided a demand is made upon them for the production of these fuels.

Adoption of these specification fuels would be of great advantage in the development of the high-speed Diesel in this Country; but who can prevent, for instance, a Cuban purchasing agent from buying local fuels on a price basis? A Cuban power-generating plant is known to buy poor fuels that wear out cylinder liners every two years. These liners cost $1,500 apiece installed, yet economy demands the purchase of locally available cheap fuels. The Diesel engine is a prime mover designed essentially to show high economy by the consumption of fuels of cheap grade; that is the inherent reason for its existence. Consider, for example, a large steamship company operating 30 vessels, two of which are motorships. Annual contracts are made to supply one grade of fuel for all of these ships, which grade shall be economical for the steamship and yet burnable in the Diesel engines.

An article illustrating the situation existing in the marine field is quoted in part as follows from the March issue of *The Motorship* (England):

> All engine builders who are rapidly developing air-less-injection machinery should therefore experiment continuously with every possible grade of fuel that is likely to be supplied to ships and should improve their fuel-injection systems until they are proof against any disability dependent on the variations in the grades of fuel available at the numerous bunkering stations throughout the world.

Similar comments undoubtedly will appear with reference to automotive Diesels shipped to foreign lands. The distribution of a world-wide product cannot be confined to those districts in which specification fuels are economically available. The solution of this problem is, therefore, a matter of obtaining satisfactory combustion of fuels that are geographically available.

Maintenance Cost May Offset Fuel Economy

(2) The demand for automotive oil-engines is also fostered by the need of an internal-combustion power unit that will have such economical consumption of cheap fuels as to cause a reduction in the total operating cost when compared with carbureter engines.

It is commonly accepted that the fuel cost of the

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Diesel engine is one-fifth of that of the gasoline engine. When considering the total operating cost, however, the maintenance cost is of serious consequence, as it can easily offset the fuel saving. The chief factor influencing maintenance cost is combustion. It is incumbent upon the fuel system to keep the engine sufficiently clean to prevent excessive upkeep and high replacement costs. Wear is seriously increased by the constant accumulation within the gas-swept spaces of hard carbon resulting from improper combustion.

Lubricating-oil cost is also determined by combustion conditions. The present automotive Diesel engine usually is extravagant on lubricating oil.

First cost of the engine can be successfully reduced by utilizing production methods on a production-type design, but the delicately fitted parts required by the fuel system must be produced by specialists provided with sensitive tools and high-accuracy instruments. A comparison of Diesel-engine first cost in the marine field, where semi-production methods are employed in Europe, as against intermittent construction in America, is indicated by the fact that a European motorship can be purchased at a price of $50 to $90 per ton, whereas an American price ranges from $160 to $180 per ton.

The type of service also influences the economic value of Diesel equipment. For instance, it does not seem reasonable to expect that a motor-truck equipped with a Diesel engine and ordinarily averaging only 10 miles per day on city streets should show economic advantages over a lower priced gasoline-driven truck. The local oil companies have found it economical to install gasoline engines in Bay tankers of 100-hp. or less where short operating time does not make possible the realization of savings in fuel consumption. On the other hand, the high load-factor of the tractor engine makes it an ideal application for Diesel-engine installation.

Reduced operating cost involves the solution of completeness of combustion over wide ranges of load to reduce maintenance cost, thereby warranting a wider adoption of the Diesel engine. This would result in higher production with consequent lowering of first cost.

Reliability over Long Periods Required

(3) Service demands reliability over extended periods of operation with full-load capacity throughout the operating period.

The question of what constitutes full load in a Diesel engine is difficult to answer. In a gasoline engine, wide-open throttle is an established condition of maximum load. In a Diesel engine, however, it is quite possible to develop high loads but with extremely unsatisfactory combustion conditions. Higher loads than those obtained in gasoline engines can be developed for limited periods, but the exhaust will be so black that this form of operation cannot continue. Full load has often been said to be that load at which best fuel economy is obtained. Usually it is necessary to extend the load rating beyond this point for commercial reasons. Therefore it is advisable to consider full load as being that load which can be sustained over extended periods of operation without undue maintenance cost. This can be determined only by tests extended over long periods.

How to develop high continuous horsepower per pound of material is still a problem. The brake mean effective pressure of a Diesel engine does not approach that of a gasoline engine; it usually ranges between 65 and 80 lb. per sq. in., whereas a gasoline engine can be rated at 90 lb. per sq. in.

Improved methods of fuel introduction will substantially raise the brake mean effective pressure of a Diesel engine. Such improvement must produce a more intimate intermixing of the fuel with the total air available within the combustion-chamber. If the fuel can be introduced in a condition ready for immediate combustion, and if the air can be brought to the point of fuel introduction as fast as chemical combination of the fuel is required, high brake mean effective pressures will result.

Difficulties with many automotive Diesels occur at idling loads. Cylinder firing becomes irregular because of erratic atomization of minute quantities of fuel, or the measuring device fails to distribute the required fuel to the respective cylinders properly.

Combustion conditions for full load may so predetermine the characteristics of a fuel system as to cause an unbalanced relation of factors for variable-load operation. Some fuel systems have difficulty in preserving atomizing quality at light loads or slow speeds. The present automotive Diesel is characterized by a delicate state of equilibrium which often is easily disturbed under variable-load operation. The solution of problems relating to reliability involves efficiency of combustion over the entire operating range.

Should Be Easy To Start and Control

(4) The automotive Diesel engine is required to be available after periods of idleness without the necessity of undue overhauls or delicate adjustments.

In this respect many high-speed Diesels can be said to have prima donna temperaments. Very often adjustments of delicate timing are required to enable the engine to develop full load after periods of idleness. Compression pressures may vary sufficiently to produce irregular operation. Leaks may develop or injection parts become clamped and bind. Starting may be difficult under certain physical conditions. The method of starting is pertinent with relation to wide service-application. Experiments are being conducted with electric starters, gasoline-engine starters and impulse-type starters. Small power equipment will not warrant the expense of elaborate starting devices, and much improvement in this respect is desired.

The automotive Diesel engine should be capable of withstanding ordinary physical conditions, and satisfactory and mechanically reliable combustion-producing mechanisms should assure consistent operation.

(5) The automotive Diesel engine should provide operating ease with the minimum of controls and adjustments.

Delicate timing and accurate settings cannot be expected at the hands of unskilled labor. The aim of the Diesel-engine designer is to produce a fuel system in which the replaceable units shall not require delicate adjustment outside of the factory. The ideal, therefore, has been to incorporate the combustion-control mechanism in a single unit. The old surface-ignition engines proved to be very satisfactory in the hands of unskilled labor, because of the simplicity of the controls and the easy unit replacement of delicately fitted parts. The unskilled operator was not called upon to make any accurate settings or perform any adjustments of his own

volition. Operating ease is, therefore, to be sought for by simplicity of combustion control by means of foolproof mechanisms that are readily replaceable without elaborate adjustments.

Difficulties of Securing Smooth Operation

(6) The automotive Diesel must show smooth operating characteristics with fairly clean exhaust.

This problem is closely related to the rate of feed of atomized fuel to produce the desired rate of combustion within the cylinder. If this ideal is to be realized, the fuel system will require a pump mechanism to provide storage of fuel under pressure. The required quantity of fuel could then be measured prior to the combustion period and be made available for the fuel-introducing device. The atomizing mechanism could be started into action at the desired time and subsequently control the rate of introduction of fuel in a regulated way to produce the desired combustion characteristics within the engine cylinder. The air of combustion must also be presented to the incoming fuel so as to coordinate the combustion process.

Present Pump-Injection Fuel Systems

Present pump-injection fuel-systems require the fuel pump to develop pressure head during the short injection period allowable and also to measure accurately the quantity of fuel required for combustion. The rate of introduction of fuel is determined by the fuel cam that actuates the fuel-pump plunger. In one 800-r.p.m. Diesel engine, the total injection period amounts to 0.006 sec., the fuel introduction at full load is 0.011 cu. in., and the injection pressure is 4000 lb. per sq. in. This small quantity of fuel is introduced into the cylinder at an initial velocity of 200 ft. per sec. The quantity introduced at idling load is probably only 0.002 cu. in. Such minute quantities, distributed to several cylinders, involve accuracies in measurement that are now quite easily obtainable. The main difficulty in this system is the introduction of the fuel at the desired rate with correctly proportioned atomizing effect. Further difficulties are encountered due to pressure surges in the fuel lines, which tend to destroy the atomizing efficiency of the fuel nozzle.

In the common-rail system, storage of fuel under pressure is maintained directly in the nozzle. The fuel valve is mechanically controlled to measure the quantity and the rate of introduction of fuel at the fuel tip. The chief problems involved in this system are the distribution of accurate quantities of fuel under all load conditions and to keep mechanical complication at the minimum.

Any erratic disturbances in either the common-rail or the pump-injection fuel system influence the combustion process detrimentally and upset the delicate equilibrium of coordination of the three principal factors determined by the fuel system, namely: (*a*) atomization, (*b*) distribution and (*c*) penetration.

Air-Injection and Solid-Injection Systems

The combustion-chamber must also present the trapped air for combustion in such form that the maximum surface of fuel shall have contact with the maximum surface of oxygen. In the air-injection process, atomized fuel prepared for combustion within the fuel-valve body is carried into the combustion-chamber on a vehicle, namely, the injection air. The air employed for injection has probably 10 times the volume of the introduced fuel. Therefore, to determine the rate of introduction of fuel in a large fluid stream is a relatively easy problem.

In the solid-injection system, sufficient energy must be imparted to the small quantity of fuel within the fuel nozzle to propel the fuel to the desired locations within the combustion-chamber. This introduced quantity, being one-eleventh of that introduced in the air-injection engine of similar horsepower, must be controlled as to its rate of introduction under pressures four times higher. This imposes problems on solid-injection fuel-systems that have not as yet been thoroughly solved. An attempt at this solution has been made in the precombustion-chamber engine, in which a small portion of an injected fuel-spray is burned for the purpose of furnishing a vehicle for carrying into the main combustion-chamber the larger bulk of fuel to be consumed.

Up to the present time the air-injection system has provided the most flexible means of combustion control. The air-injection process, however, is out of the question for high-speed work, because of the expensive and troublesome high-pressure air-compressor unit.

The solid-injection system would be welcomed if it could be made to approach the combustion control of the air-injection system. The latter not only provides accurate controlling means but the injected spray is thoroughly permeated with oxygen which assists in speeding up the ignition of the fuel particles. The solid-injection spray often has a core of coarse fuel-particles that do not have access to sufficient oxygen to complete their combustion. Often, again, a solid-injection spray will have a rate of introduction and a retarded degree of atomization that result in a large portion of the introduced fuel being enveloped in a cloud of carbon dioxide, thereby preventing complete combustion of the fuel introduced.

Advances have been made in the use of turbulence to disperse the fuel particles sufficiently to provide them with the necessary oxygen for combustion.

Ignition lag has a serious influence on smooth operating-characteristics, as violent explosions following greatly delayed ignition will cause explosive pressures to build up with extreme rapidity in the combustion-chamber. Rough running can be prevented only by controlling the increment of pressure rise during the combustion period, which factor is limited to a definite value per degree of crank angle. Smooth operation is therefore to be attained by the regulated control of the combustion process within a definite rate.

Opportunity To Coordinate Satisfactory Functions

The factors that have been analyzed herein as retarding the broader adoption of the Diesel principle for automotive work have all been focused around the combustion process. The picture presented appears to be fraught with difficulties. The fact that no one fuel-system is a panacea for all of the ills of combustion is not to be regarded as shutting out hope for an oil engine that can take its place in the automotive field.

The opportunity exists to cull those operating functions which gave satisfaction and, by persistent research, to so coordinate these factors that a practical solution will be obtained, thereby broadening the scope and the sales opportunities for the automotive oil engine.

Amphibian Design *and* Transportation

By GIUSEPPE M. BELLANCA[1]

Metropolitan Aeronautic Meeting Paper

THE PUBLIC has been waiting for the amphibian plane for a very long time, in fact, it has been demanding a craft that can travel on land, water and air, can take off vertically from any small place and land equally well in these same places. We know what the public wants, but how can we best satisfy this demand? We are complaining of business being slow, when all we have to do is to build what the public wants. Unfortunately we do not yet know how to make a craft that can satisfy the demands. In aviation, as in everything else, we must move gradually. Before the first practical flights with airplanes, taking off and landing were done on water, as landing on water was considered safer than on land. We know of Langley's flights. We know of Bleriot's first three planes which were intended to take off from the water. One of these, made in 1905, was a glider with pontoons which took off from the water by being towed by a motorboat. It fell down soon afterward. The Bleriot No. 3, finished in 1906, was a seaplane with a 24-hp. automobile engine. The trials of this plane also ended in a failure. As we all know, the first successful flights of Bleriot were made in a landplane. Taking off from the water at that time was more of a problem than taking off from land. The knowledge of how to make proper pontoons for planes was almost non-existent and that, coupled with the additional weight necessary for flotation, discouraged the first pioneers. So the first flights, both in this Country and in Europe, were made with landplanes.

Sufficient reduction of weight and air resistance is the greatest obstacle to be overcome in designing amphibians.

Landing gear weighs from 5 to 7 per cent of the gross weight of the plane, or roughly about 30 per cent of the payload, and, if exposed, reduces the speed approximately 6 per cent.

Combining a landplane and a seaplane in a machine that will perform as well as either in its own element is difficult.

One attempt to solve the retractable-whel problem uses a well at the front step of the pontoon in which the wheel slides up and down, projecting only when the plane is landing.

Weight and Resistance Two Great Handicaps

The public, however, kept demanding a water craft and that demand was finally satisfied. It also kept on asking for the amphibian and it is also getting that. The worst difficulties to overcome in aircraft are weight and resistance. Those difficulties exist more in seaplanes and still more in amphibians. Probably these difficulties caused the landplane to come before the seaplane and the seaplane before the amphibian.

Let us take for example a medium-sized cabin plane, our Pacemaker. The gross licensed load is 4300 lb.; the empty weight, 2368 lb. Taking this from the gross we have a disposable load of 1937 lb. minus 895 lb. for pilot, gas, and oil, which leaves a payload of 1042 lb. The same plane on floats weighs 2863 lb. or 500 lb. more than the landplane. By taking this additional weight, due to the floats, from the payload we would have left a payload of 542 lb. If in addition we desire to put on a land landing-gear, the weight of which would be approximately 250 lb., the total payload remaining would be only 292 lb., too small a load to make the plane sufficiently attractive for anybody to buy for around $19,000. Fortunately, the load factors required decrease with the increase in the gross weight, thus increasing somewhat the allowable gross-weight itself. But that increase is not sufficient to give us the required payload. The maximum speed of this plane on land is 145 m.p.h., while on floats it is only 135. What has been said for this plane applies also to others.

In the case of our Pacemaker the margin of strength of the plane enables us to have it licensed as a seaplane with a payload of 1042 lb., this being exactly the same as that of the landplane. If we should desire to put wheels on it, the probable payload would be about 800 lb. I believe, however, that we will find a way by which, through appropriate changes, we can increase the payload to 1000 lb. A superficial investigation of the percentage weight of a land landing-gear in a seaplane or flying boat shows this to vary from 5 to 7 per cent of the gross weight or roughly some 30 per cent of the payload, a remarkable percentage. The reduction of speed in the case of the exposed landing-gear I find to be approximately 6 per cent.

In the face of such difficulties, we are not surprised that the development of amphibian planes has been slow. Building an amphibian in the past would have been useless because of the heavy engines, the limited knowledge of airplane structural design and the inferior material. Formerly we were using mild carbon-steel of a maximum tensile-strength of 55,000 lb. per sq. in. almost exclusively, while now in its place we are using steel with a tensile strength of 95,000 lb. per sq. in. and duralumin of 55,000 lb. per sq. in. very exten-

[1] M.S.A.E.—President, Bellanca Aircraft Corp., New Castle, Del.

sively. That situation would have made carrying any payload impossible a few years ago.

Only after the war did we have reasonably successful amphibians. One of these was the Supermarine Seagull brought out in 1921 in England by the Supermarine Co. This flying boat, with retractable wheels on each side has met with marked success, having been used largely by the English Navy. This amphibian, powered with the 450-hp. Napier engine, has an empty weight of 4000 lb. and a gross weight of 5860 lb., allowing a useful load of 1860 lb. The maximum speed is 108 m.p.h. and the landing speed 47 m.p.h. In this Country the first successful amphibian was the Loening amphibian. When this plane first came out the DH-4 airplane was very much in use and to see that funny-looking amphibian with the Liberty engine showing as good, if not better, performance than a landplane with the same engine was remarkable. The design of the Loening is remarkable for its low resistance and the combination of all is such as to give it great strength and roominess, considerable speed and maneuverability. As a multi-engined amphibian the Sikorsky is a remarkable airplane which, in spite of being an amphibian, is able to fly on a single engine with full commercial load.

How to Improve the Amphibian

I have already explained and emphasized that the main difficulties for amphibian design are weight and parasite resistance. To talk of seaplane or landplane design is unnecessary. We are interested in how to put the two together so that the resulting plane will perform on water as well as a water craft and on land as well as a landplane. A successful amphibian today cannot but be of fine design. The landing-gear for water or land, due to resistance alone, absorbs a big percentage of the power. The weight and resistance of the two together make the problem very difficult.

GIUSEPPE M. BELLANCA

In the face of all this, the amphibians now on the market are remarkable examples of good design. However, we must improve them. We must increase the percentage of payload. We must increase the speed. The increase of payload and speed are essential because, to make the amphibian popular, it must be made useful enough so as to be bought not only by the wealthy people, or a few transportation companies, but also by people of moderate means who need first of all usefulness proportionate to the cost. How are we to improve them? To say that we have to do this or that is easy, but to do it is harder. Simplify the design, cut down weight, cut down resistance, do that without taking from its strength; in fact, increase the strength. Are there any other suggestions to offer? We are all in the same boat. What I have said, you already know. If you know how to make a very good flying boat and you add retractable wheels, you have a good amphibian. The same is true of a very good seaplane; by adding wheels, you again would have a good amphibian. The main part of the amphibian's work comes when we have to put the wheels on. The easiest way is to put them on the outside. We know that in this manner the water gear will remain untouched and all that is ncessary is to make the landing-gear answer properly for all its requirements. A better way is to put the land gear inside some part of the plane so that it will be out in the stream of the air only when landing on land, at which time its resistance is not detrimental. To do this is more difficult and some will say it is unnecessary. I am stating here my opinion of what can be done in the immediate future. In one of our experimental planes we retracted the wheels in the lower stub wings to make a landplane that was easily convertible to an amphibian by adding two pontoons, thus eliminating the resistance of the land landing-gear.

Recently an interesting new type of amphibian, the Aeromarine Klemm, made its appearance in the market. It is a monoplane on floats. Each float, at the step point, has a well into which a wheel slides up and down. The wheel projects on the underside of the pontoon when the plane lands on land and is retractable inside the well when the plane is to land on water. On the forward part of each float is located an additional small wheel which is needed because the main wheels are located apparently behind the center of gravity of the plane, thus preventing nosing over. This system makes possible the saving of some weight and especially the reduction of considerable resistance. Nevertheless, I think that omitting the front wheel would be better. The Edo Company is also experimenting with a similar pontoon.

At present we are experimenting with a single-engine, water-cooled airplane, substantially like our Model K Sesquiplane, with a Hornet engine, which is intended to be convertible from a landplane to a seaplane or amphibian. I hope in the near future, after we have tried this plane, to be in a position to describe it fully and to tell of its results. The use of pontoons with the wheels inside promises to be very successful, as it answers the first prerequisite of light weight and low resistance. The installation in the Aeromarine Klemm monoplane is reported to be very successful, making a difference in the take-off time of an amphibian, as compared with the seaplane type, of only 3 or 4 sec. In these pontoons the well is left open. From a wind-tunnel test that we ran some time ago on a float for internal wheels, we found that the resistance is considerably higher when the well is left open on the underside. I think that we should find a way to close the well.

Transportation Advantages of the Amphibian

The advantage of transportation with the amphibian cannot be overestimated. It makes the saving of considerable time possible on many occasions. We have seen that obtaining conveniently located fields in big

cities has been very difficult. The price of land in central localities is very high, and this has rendered the location of fields close to residence and business districts impossible. Fields in big cities usually are far away from the center, thus limiting the usefulness of flying for short distances. Coming to New York City from New Castle, Del., a portion of time saved by the plane is lost on the trip from Newark airport to the city. Conditions around New York City are changing with the completion and improvement of nearby airports. The amphibian, without waiting for airports, would save considerable time. On the other hand, we must not forget that the amphibian at the present time is slower than the landplane. This decrease in speed on short runs cuts into the time saved and on long runs makes the amphibian far inferior.

Transportation with amphibian planes, if they are made as strong as landplanes, over places appropriate to the type, is on the whole safer than with seaplanes or landplanes. The reason is that the amphibian has, in addition to all the land fields, all the rivers, lakes and bays on which to land; also a body of water is easier to see and find. The fact that one has a choice between land and water gives the amphibian a marked advantage over the seaplane and landplane. De Pinedo, when planning long flights, preferred the seaplane especially because he could plan in advance for his stopping places, easily finding on the maps the location of bodies of water suitable for seaplane landings. A great advantage of the amphibian is its ability to get to land under its own power after it has landed on water and from land to water. Pulling a seaplane on land or getting a seaplane or flying boat to the water is a costly affair. The amphibian renders all this very simple. Housing an amphibian is far easier than a seaplane because of the present scarcity of seaplane bases. But all this is subordinated to the condition that the amphibian must carry adequate payload, must have sufficient range and high speed, must climb and take off well and must be strong and safe. To sacrifice any of these qualities to any extent would be a decided disadvantage. Proper design is essential.

THE DISCUSSION

A. A. GASSNER[2]:—Mr. Bellanca's paper has covered the subject rather well, and he has outlined the difficulties with which we have to figure in designing amphibians. Most of the trouble in designing amphibians is the weight question. The Fokker Aircraft Corp. has never tried to build an amphibian by using a seaplane with floats and adding some wheels to it. We believe in taking a flying boat and making it usable as an amphibian, and we think that is better all around and as far as seaworthiness is concerned.

C. H. BIDDLECOMBE

As far as the use of an amphibian in this Country goes, it is more limited than appears at first sight. First of all, we have the ice question. In practically all of the country north of New York City, on the Great Lakes, all the lakes of Minnesota and similar places where an amphibian is very useful, its use on water is out of the question for the winter months, from, say, December to March.

The possibility of landing an amphibian anywhere sounds very good as long as we do not have to figure on side winds. Many little lakes and rivers are somewhat narrow but look all right to land on until we consider side-wind conditions. To land an amphibian or a flying boat on a narrow stream or a small pond is just as bad as a forced landing anywhere else, because the wind seldom blows right from where we want it for landing.

One item that Mr. Bellanca did not mention is the price. Unfortunately we have to run up higher in the price with an amphibian than with a seaplane or with a landplane, and the operator, whether private or commercial, has first to decide what is more useful to him, a seaplane or landplane or whether he has to have absolutely an amphibian type. In most cases, the one or the other selection can be made. For small private ownership I believe the amphibian to be very useful and that it will come into great and extended use in the very near future.

CHAIRMAN C. H. BIDDLECOMBE[3]:—One of Mr. Gassner's points that appealed to me was that amphibians are amphibians and not flying boats. In other words, when the ice closes up the lakes, we still have a large number of good airports on which we can land our amphibian in the winter. We wait for the ice to go out and we use it as a boat again in the summer.

J. C. HUNSAKER

JEROME C. HUNSAKER[4]:—The amphibian designed as shown by Mr. Bellanca is an effort to obtain an increase in the flexibility of landing, so that the machine can land on more places, and as such we pay a certain price for it. Under the conditions of operation, the owner must decide whether he wishes to pay that price. I would be interested to know what percentage of the payload must be sacrificed to get the amphibian feature into it.

RICHARD M. MOCK[5]:—Mr. Bellanca estimates that the weight of landing gear is usually 5 to 7 per cent of the gross weight of the airplane, and taking an airplane and putting a land landing gear on it would mean about

[2] M.S.A.E.—Chief engineer, Fokker Aircraft Corp. of America, Hasbrouck Heights, N. J.

[3] Lecturer on air transport, New York University, New York City.

[4] M.S.A.E.—Vice-president, Goodyear-Zeppelin Corp., Akron, Ohio.

[5] Jun. S.A.E.—Consulting aeronautic engineer, New York City.

30 per cent of the payload. In the type of airplane that Mr. Bellanca suggests, where we have a structural system such that we have to support floats and incorporate wheels at that point so that the load is almost in the same system of structure, the additional weight is very small. It might be half of what it would be in the other instance that I mention.

Mr. Gassner mentioned the flying boat versus the twin-float seaplane and said that he concentrated all his activity on the flying boat because of the advantage of seaworthiness. I do not think we should lose sight of the fact that Savoia has had great success with the twin-hull flying boat which, from the point of view of seaworthiness, is almost the same as the twin-float seaplane.

CHAIRMAN BIDDLECOMBE:—Will Mr. Gassner give us, if possible, the Fokker company's experience regarding how much more weight must be added to a flying boat to make it feasible for amphibian use?

MR. GASSNER:—On a ship of about 7000-lb. gross-weight, about 400 lb. for the landing gear, which agrees rather closely with the statement of Mr. Mock, Mr. Bellanca's representative. This includes all the mechanism—wheels, axle and tail skid—which is about the same percentage as Mr. Bellanca states. We have tried various systems and find that mechanical-retraction mechanism runs some pounds lighter than hydraulic gear.


RICHARD M. MOCK

We have also conducted some experiments with stub-wing floats in which the wheels are retracted, and some experiments along that line will be continued within the next few months, since we believe that some of the weight increase which is inherent in an amphibian can be avoided in this way.

A MEMBER:—A landplane requires a landing gear, which would be the same as the landing gear on an amphibian, and the additional weight is due to the fact that we want pontoons or a hull for landing on water. The retracting mechanism, whether it is mechanical or hydraulic, of course adds some weight over and above what we would have on a landplane.

One biplane, which is a five-passenger job, including the pilot, requires a 425-hp. engine to make it a successful job. For a five-passenger pontoon job we would only require a 300-hp. engine which would perform equally well.

CHAIRMAN BIDDLECOMBE:—The main point in considering the boat and the pontoon job is rather a question of the sturdiness of structure that we can get into a boat hull as compared to the comparatively flimsy structure essential in pontoon construction. I think greater stability and the ability to ride out rough weather gives the boat a big advantage over a pontoon, with the result that we can perhaps afford to use the larger engine mentioned in place of the smaller one.

A MEMBER:—Last winter a flying boat went up in the Maine woods and the pilot thought that he was landing on ice, with his wheels down. What seemed to be ice was just snow lying on top of logs floating in the lake of a logging camp, and naturally the wheels went right down through the logs, and the ship nosed up somewhat. He finally was able to hoist the landing gear and then plow through the logs to the shore and leave the plane there overnight. He was frozen in the next morning and had to use dynamite to get a road clear. Then he turned and used what open water was available and skidded off the water on the ice without using the landing gear, just on the keel of the ship, and then put the wheels down and took off. That is a rugged construction we certainly would not be able to get with pontoons.

S. C. FINGER[6]:—I do not see much future for the twin-float amphibian airplane because the twin-float seaplanes are giving too much trouble in the float gear. The weight of a flying boat or amphibian depends entirely on the ingenuity of the designer. Some flying boats today are probably too heavy in the hull. Some very low-priced amphibians are giving satisfactory service so far as I have been able to ascertain. The price runs from $7,300 up. One amphibian that I am familiar with sells for $17,500 and lands continually in very severe water conditions and often has been taxied on mud without any trouble. The whole problem involved in the flying boat is a matter of the ingenuity of the designer.

GEORGE A. PAGE, JR.[7]:—Perusal of some of the advertising of the Italian Savoia Marchetti Co. shows that it manufactures a ship of the single-hull type that is similar in gross weight with the twin-hull type that we are familiar with in this Country. The former carries more useful load and consequently more payload; has a higher performance, both in speed and climb, and therefore indicates better all-round aerodynamic efficiency. From a little study of the twin-hull design we find that it was built primarily for the Italian Navy as a torpedo carrier and probably would be less suited for true passenger carrying than the single-hull ship.

MR. GASSNER:—One question that has not been brought out yet in this amphibian discussion is corrosion. On landplanes we have no trouble with corrosion by sea water, and on seaplanes and amphibians this question has to be considered very seriously and it is one of the reasons also why amphibians are more expensive. They require better protection with paint.

CHAIRMAN BIDDLECOMBE:—The general consensus of opinion would seem to be that the hull type of construction rather than the pontoon type is probably the most suitable for amphibian development; that is, airplane and boat designers seem to prefer to put wheels on boats rather than try to put wheels on pontoon equipment.

MR. MOCK:—Two other types of amphibian that we have not mentioned have been used, but I do not think they are developed commercially. One is the single-wheel type developed by Grover Loening, which is a flying boat with little wing floats. The other type is that developed by, I think, the Cadillac Aircraft Corp. in Detroit and also the Cutty Sark by Saunders-Roe in England, having a flying-boat hull with closely coupled wing floats housing wheels similar to those used in the Cutty Sark twin-float seaplane, giving the flying boat's seaworthiness combined with aerodynamic efficiency.

[6] A.S.A.E.—Consulting aeronautic engineer, Far Rockaway, N. Y.

[7] M.S.A.E.—Design engineer, Curtiss Aeroplane & Motor Co., Garden City, N. Y.

Weight Saving by Structural Efficiency

18th National Aeronautic Meeting Paper

By Alfred A. Gassner[1]

Weight saving is one of the essentials of airplane design and increasing structural efficiency is a way to decrease weight. Increasing the structural efficiency to save 4½ per cent of the weight of an empty airplane will give on an average a 13½-per cent increase in the payload without increasing the gross weight.

Structural efficiency in airplane design represents a compromise, as aerodynamic efficiency overshadows all other characteristics, and the battle between the two has been waging ever since the first airplane flew.

Aspect ratio, design load, wing area and maximum wing-chord all influence the weight of cantilever wings of similar design.

Logical development of cantilever-wing design is the coque or shell form where the number of elements is the minimum.

Stiffness is a criterion for judging a wing structure, since an apparently safe reduction in strength may produce an unsafe reduction in stiffness.

Structural analysis is one of the most important items in selecting the basic structure as airplane structures are probably the most complex systems submitted to the structural engineer for attention.

Selection of the basic structure and the best-suited material are closely interconnected and both questions will have to be decided more or less simultaneously.

AIRPLANE design is still a complex combination of science, experience and art; efforts to make it a purely mathematical problem that can be solved merely by application of tables, slide rule and calculus have seldom met with entire success. In a world not yet perfect, each modern airplane, for whatever purpose designed, is the result of compromises, numbering from a few to a few hundred according to more or less divergent specifications of sales departments or customers. We cannot design the perfect airplane. Each ship built has certain advantages and shortcomings, in comparison with other airplanes designed for the same general requirements. To make this compromise in the most efficient way or at least in what appears at the moment to be the most efficient way, to win much on one side without losing any or but little on the other, is the hard task confronting the designer every day anew.

The weight of the empty plane is one of the most important characteristics of any airplane, military or commercial. Therefore, weight saving is one of the essentials of airplane design; however, this must be accomplished without decreasing other important valuation factors of the plane. One of the very few ways to decrease weight is to increase structural efficiency.

Classes of Weight

In a study that will be published shortly we have analyzed the percentage of weight which can be influenced by the airplane designer. We found that on 35 per cent of the weight of the empty plane the designer has no influence whatsoever. This group includes engine, propellers, starter, wheels and tires. On 20 per cent of the weight empty the designer has limited influence. This group is made up of fuel and oil tanks, floors, bulkheads, chairs and windows. The third group of structural parts such as wings, fuselage structure, tail surfaces, controls and landing gear without wheels comprises only about 45 per cent of the weight empty of the ship, and this is the one group where the weight is entirely dependent on the skill and experience of the designers and structural engineers. A saving of 10 per cent of the structural weight can be accomplished only by most careful consideration of every detail together with the basic design, and still this 10 per cent will bring only a 4½ per cent reduction of the weight empty.

Useful loads of modern commercial airplanes amount to approximately 40 per cent of the gross weight, which means, of course, that the weight of the empty but fully equipped ship is making up the remaining 60 per cent of gross weight. Only about half of the useful load is disposable payload; the rest is made up by the weight of crew, fuel and oil and special equipment. If we save now by structural efficiency 4½ per cent of the weight of the empty ship, we can increase the payload by 13½ per cent and still have the same gross weight. If a ship has a gross weight of 12,000 lb., this means the original payload of 2400 lb. can be increased by 320 lb. to 2720 lb., which means that two additional passengers or an equivalent weight in express matter or mail can be carried without additional expenses. Since a passenger mile in air traffic is sold now at approximately 7 cents, and since a ship with a life of 3000 hr. flying time at an average cruising speed of 100 m.p.h. travels a total of 300,000 miles, the income during these 3000 hr. will be increased by fully $21,000, assuming, of course, that our public gets really airminded and uses the additional available seats which have been made possible by the brain work of some engineer.

Structural efficiency in airplane design invariably represents a compromise, not only in itself and in estimating, calculating or guessing the pro and con for various basic designs, but also a compromise for the sake of fulfilling given requirements, outside of the strictly structural class or range, which requirements, however, may necessitate modifications of the structure, which makes the solution less efficient.

Characteristics of Structural Efficiency

We can state that structural efficiency in airplane design has three characteristics:

[1] M.S.A.E.—Chief engineer, Fokker Aircraft Corp. of America, Hasbrouck Heights, N. J.

(1) The choice of a basic structural system best suited for aerodynamic, space and wear requirements
(2) The choice of the kind of material best suited for this chosen basic structure
(3) The using of the selected material or materials in such a way that the least quantity of material gives the required strength.

The first characteristic of structural efficiency—choice of basic structure—of necessity already contains one of the indications of compromise. We can seldom select the most efficient basic-structure and subordinate all other requirements. The plane first of all has to fly with minimum of power and maximum of useful load and speed. That the structure has to be strong enough is, of course, expected. Aerodynamic efficiency is, however, the all-overshadowing characteristic. We have also to take care of the demands for cabin and tank space, doors, windows, aisles and mounting of engines and others of a similar nature, all of which must be considered ahead of structural questions and all taken more or less at their full value and as immovable and without compromise on their part.

The commercial airplane is a transportation vehicle and has to serve the public in the same way as a common carrier does. This means installation of comfortably upholstered chairs, heating systems, large windows, solid floors and pleasing ceiling and wall decorations, depending upon the quality of service to be rendered. Practically every one of these items had to be newly developed on account of space and weight questions; nothing could be taken from existing motorcoach or railroad experience. Three or four years ago, airline operators were satisfied when they could offer their passengers a plain and simple little cabin with a few wicker chairs. The latest types of ship of the large three and four-engine classes can easily stand comparison with any deluxe motorcoach or parlor car, and sleeping accommodations have already been installed in a number of privately owned ships. All of these requirements had to be fulfilled to make the commercial plane into the transportation vehicle it is today. Many or most of these requirements did necessitate creation of new types of structure or extensive changes on existing structural systems.

The foremost essential parts of a present-day heavier-than-air flying vehicle are the wing system, the structure that houses pilots, passengers or other disposable load, engines, fuel and oil tanks, the control surfaces and the landing or flotation gear. From the very first actually flying airplane to the latest giant passenger airliner, we can follow the constant struggle between the aerodynamic and at the same time structural efficiency. Literally hundreds of wing-bracing systems have been experimented with, some with marked and lasting success, others seemed from the very beginning to be merely convulsive attempts at originality.

Monoplanes, biplanes, sesquiplanes, triplanes and tandems had all been designed as early as 1910, some with wires, some with struts as bracing devices and some without any external bracing and depending on the internal wing-structure for cantilever support. The flying machine of the early days gave a striking impression of lightness. But when the useful load and performance had to be increased, more efficient structures had to be designed; the mere plank of wood that constituted the wing spar was transformed first into an I-beam by routing out at the neutral axis, then it was tapered in width and finally replaced by a built-up box spar with tapered flanges and webs.

Sections Used in Metal Construction

In the field of metal construction, the common I-section of structural-steel design as used in building and bridge construction is replaced in airplane design by an appropriate light truss or by an I or U-section, using for webs very light gage sheet with reinforcement channels. Lately a European designer has not hesitated to use tapered sheet metal and has constructed spar flanges and webs with the gage of the sheet decreasing gradually toward the wing tips.

Rational design almost invariably leads to the body of equal strength; wing beams, interplane struts and fuselage structure must be designed so that the ratio of ultimate strength over required design-strength remains practically constant over the full length of the individual part. This is only one of the considerations leading toward this efficiency. Most of them are assumed in the following expression to follow the laws of the strength of material; to design simple rigid structures having the material as far as possible from the neutral axis, avoid eccentricities as much as possible and reduce the bending, since a so-called pin-joined beam is always lighter than a beam in bending.

In the preliminary design, a homogeneous, simple, calculable system, following a theoretical law, should be considered. There, considerable saving in weight

TABLE 1—VALUES OF *K* FOR EIGHT TYPICAL WING-SECTIONS

Wing	Fokker F-VII	Fokker C-2	Fokker C-2A	Fokker XLB-2	Fokker F-X	Fokker F-X-A	Fokker F-32	Junkers G24	Fokker F-VIII	Fokker Super Universal	Junkers L6 (F-13)
Span, ft.	63¼	63¼	73	73	71¼	79	99	98½	75½	51½	49
Total Wing Area, sq. ft.	618	618	748	748	718	850	1,360	1,100	890	390	469
Aspect Ratio	6.47	6.47	7.13	7.13	7.07	7.35	7.22	8.8	6.41	6.8	5.13
Maximum Chord, in.	149	149	149	149	149	170	216	165	177	120	118½
Root-Rib Camber	5	5	5	5	5	5	4.7	5	5	5	5.55
Proportional Chord, in.							230	5			106¼
Gross Weight, lb.	8,800	9,250	9,586	12,500	12,500	12,500	24,250	14,300	13,700	5,150	3,910
Wing Weight, lb.	1,050	1,280	1,750	1,750	1,760	1,887	3,526	3,300	1,950	800	596
Design Weight, lb.	7,750	7,970	7,836	10,750	10,740	10,713	20,725	11,000	11,750	4,350	3,314
Load Factor for High-Incidence Condition	4.5	5.5	5.5	4.5	4.5	4.5	4.5	4.5	4.5	6	5.5
Design Load, lb.	34,850	43,800	43,100	48,300	48,200	48,100	93,260	49,500	52,750	26,100	18,200
Maximum Chord *Aspect Ratio* × *Design Load* × *Area*	935	1,175	1,545	1,665	1,650	1,770	3,980	2,900	1,700	575	413
K	1.122	1.09	1.132	1.05	1.07	1.065	1.13	1.138	1.15	1.39	1.445

can be made due to the fact that a consistent and thorough system of design is carried out, thus giving the different parts a correct proportion and an adequate bracing. When this is done, each part should be studied to determine the form that will allow the greatest inertia and rigidity for a given weight.

The peculiarity of the aeronautic construction has led to the introduction of shapes such as are not commonly used for other construction purposes, which is a source of much grief in the drafting room where few or no data referring to these particular shapes are available. Yet the aeronautical engineer does not give up the ship, he designs wings having a parabolic variation of the thickness along the span, he strives to give any member a multifold task, he replaces a brace strut by a rigid angle, he endeavors to reduce the number of members, for his aim is: to obtain a small number of elements taking a big load, rather than a multitude of small elements taking a small load; this unobtainable ideal is a whole ship of equal resistance.

ALFRED A. GASSNER

Designing a Wing

Let us embody the above fundamental considerations into the most typical example of aeronautic construction, the wing. Like any structure, this vital part of the airplane is governed by certain fundamental laws of strength of materials, elasticity and rigidity. With members having the shape of body of equal strength and the material far from the neutral axis, the wing, especially of the cantilever type, should be thinned at the top and tapered in plan form. The variation of the thickness and the moments of inertia should follow continuous laws to the end of avoiding any discontinuity in the travel of the stresses, thus leading to what is often referred to as the "structural resonance."

Four factors seem to influence the weight of wings of similar design, in this case the standard Fokker type of three-ply covered wing which is built upon box spars made of spruce flanges and plywood webs and plywood ribs and is of the full-cantilever type. These four factors are, first, aspect ratio; second, design load, which is gross weight of the plane minus wing weight multiplied by the load factor for high-incidence condition; third, the area, and, fourth, the maximum wing-chord of tapered wings. One other important factor in the weight is the relief coming from loads distributed over the wing span as nacelles with engines, oil tanks and similar parts and fuel in the wing tanks. Obviously, aspect ratio has an effect on the weight, as with the increase of aspect ratio the span increases, and thereby not only the span lengths but also the moments of the wing loads. Design-load increase has a direct proportional influence on the weight of the wing. With increasing design loads, the wing load per square foot increases and therefore all moments. Wing weight increases with the area of increase of cover weight and of number and length of ribs, stiffeners and similar parts. Increase of maximum wing-chord gives greater spar height at the root and brings the center of area of each wing half closer to the center of the wing; the wing is more tapered for the same area and aspect ratio, therefore the wing weight is decreased.

We can write an equation for these relations as follows:

$$(\text{Aspect Ratio} \times \text{Design Load} \times \text{Area/Maximum Chord}) \times K = \text{Wing Weight}$$

In this equation we have:

Aspect ratio or the square of the span in feet divided by the wing area in square feet

Total area of wing including part blanked by fuselage, or engines, in square feet

Maximum chord at wing root, in inches

Wing weight, including ailerons, all wing and nacelle attachment fittings, inspection doors, varnish or paint, in pounds

The ratio of chord length to maximum rib-height or the maximum camber is 5 for the root section of standard Fokker wings. If this ratio is less or more for a wing whose weight must be determined, we must calculate an equivalent chord for use in the equation. If, for instance, the actual chord is 120 in. and the camber ratio is 6, which means that the maximum height of the root rib is 20 in., then the equivalent chord of the equation would be 20×5 or 100 in.

For various actual wings this factor is slightly different for single and tri-engine ships, because of the relief loads on the wing of the latter. The factor can be taken as $K = 1.1$ for tri-engine ships or other types with engines supported in wing nacelles, and $K = 1.4$ for single-engine ships. For ships with greater loads distributed over the span, the factor will probably be $K = 1.0$. The equation has also been applied to the wing of the Junkers L6 and gave a value of $K = 1.445$ for this wing and 1.138 for Junkers G24. Table 1 gives these figures for eight typical wings and we find that the factor K is surprisingly constant for all these wings, which range in area from 390 to 1360 sq. ft.; in span from 49 to 99 ft.; and in design loads from 18,200 to 93,260 lb.

Forms of Wing Construction

On externally braced thin wings the covering material is utilized only to give the wing the continuous shape of the air-foil and to support the more or less bright paint. The stiff covering of cantilever wings resists the tendency of the wing to twist, stabilizes the spars and also helps to take the bending loads. This type necessitates at least two spars and the "active part" of the wing structure is in the form of a rectangle. This method is adopted by Fokker, Wibault and Rohrbach. The multispar, interbraced structure of cantilever wings, developed by Professor Junkers, also apparently needs a fairly rigid skin to help counteract the torsional loads. A third type of cantilever wing uses two ordinary wooden box spars with a system of steel-tube pyramids between the spars to resist the torsion and a covering of fabric. This type is used on the Cessna monoplane and on the English Fairey

monoplane. Last year the very interesting design of H. J. Stieger of the Monospar Wing Co. appeared in England. This wing uses only one spar and that spar is braced against torsion in a manner very similar to the one employed in the Cessna monoplane. The pyramids are made of wire and therefore double-opposed with struts taking compression. Unfortunately, very little seems to be known about the Stieger Monospar and we do not know of a successful airplane that employs this principle.

The logical development of cantilever-wing design would seem to be the coque or shell form, where the number of elements has been reduced to the minimum. The rigid cover alone resists bending, torsion, axial load and local pressures, and the material can be distributed far from the neutral axes corresponding to the different planes of flexion. To perform these different duties, an adequate bracing system or rather a multi-coque system has to be devised.

Stiffness as Well as Strength, a Criterion for a Wing Structure

Strength is not the only criterion for a structure. Stiffness must be considered, too, as an apparently safe reduction in strength may produce an unsafe reduction in stiffness. Reduction of wing stiffness may affect the safety of an airplane, causing diminution or even complete loss of lateral control or reducing the critical flutter-speed of the aircraft. The former effect depends, of course, mainly on torsional stiffness, as a wing tends to twist, and thereby changes its incidence, under aileron loads. The other effect is associated, in addition, with the flexural stiffness of the wing and with the stiffness moment about the aileron hinge due to the elasticities of the control system. If these stiffnesses are all multiplied by a given factor, the critical flutter-speed is multiplied by the square root of that factor.

Cantilever wings, therefore, cannot be designed to fulfill only strength requirements. Elasticity and torsional stiffness have to be considered as at least of some importance. In the conventional wing the spars are the most important factors affecting wing stiffness. The flexural stiffness of the wing depends on their flexural stiffness, and the torsional stiffness of the wing on their flexural stiffness and on the distance between them. The effect of the increase or decrease of spar flexural-strength on wing flexural-stiffness is therefore a matter of primary importance. The flexural stiffness is also of greatest importance in the design of tail surfaces and fuselage rear ends, which often have to stand very rough handling by the ground crew.

Importance of Structural Analysis

One of the most important items in the selection of the basic structure is the structural analysis. Airplane structures are probably the most complex systems that are submitted to the attention of the structural engineer, and yet these structures more than any others have to be analyzed with great accuracy to determine the minimum sizes. In aeronautic matters, the statically indeterminate systems, far from being the exception, are the rule; too often strength of material is replaced by elementary geometry, elasticity by conservative assumption; and calculus prohibited. Consequently, weight is wasted through lack of thorough analysis.

Many of the mathematical operations employed in airplane design are nothing more than the solution of equations that are either empirical or are based on assumptions which are known to be inaccurate but which have been adopted because of their simplicity. These inaccuracies of the formulas can be remedied by more refined methods of structural analysis and by thorough and coordinate tests of specimens. Probably in no other field is greater refinement in the design and stress analysis required. Whenever possible, statically determined systems should be used, and when that is impossible, the system should be analyzed by the elasticity method, and tests made to determine the form factors of the specimens. That material reductions in weight are a direct consequence of the exact knowledge of the stresses in the members of an aeronautic framework should be constantly borne in mind.

Selecting the Material

In choosing the kind of material best suited for the basic structure we are somewhat freer from influences outside of the range of structure. However, selection of basic structure and the selection of best-suited material are very closely interconnected. We will have to decide both these questions more or less simultaneously. A tubular fuselage-construction can be built from steel tubes of various grades and alloys, with heat-treatment, or from aluminum-alloy square or round tubes. It can be built as a full Warren truss throughout or with tierods or wires for tension members. The choice of material will reflect back on the basic structure and will have great influence on the weight.

In selecting the material the first consideration is the suitability of the material's physical characteristics to the purpose it is designed to serve. The ideal material would be one whose strength and endurance are infinite and whose weight and rate of wear approach zero. Even the boldest visionary of the machine age has not yet set the date for its development.

Yet the remoteness of an ideal has never discouraged men from trying to reach it. Constant improvements are being made in old materials and new ones devised. Some of these have been of great help to aviation, as for instance the steel alloys that made the modern light-weight engines possible. Others, as for instance the magnesium alloys, have been tried experimentally and seemed to be very promising for a short time. The story of aluminum and its alloys is a romance in itself, a romance that has, however, blinded some people to realities. One of these realities is that Nature herself through uncounted ages has developed a building material that man could not duplicate by chemical processes, a material that is of great importance in airplane construction, and whose weight-strength ratio and endurance, especially against vibration effects, make it most interesting when compared with steel or light metal alloys; this material is wood.

The battle between advocates of all metal and those of a composite design that uses both metal and wood as construction materials has been raging for the last 10 years without definitely proving the superiority of either system. Something similarly interesting for aeronautical engineers has been going on in England for about the same period of time, the fight between monoplane and biplane enthusiasts.

If we want to save weight, we must estimate the weight of our structure closely before we begin the de-

(*Concluded on p.* 472)

Bodies *for* Front-Drive Cars

Annual Meeting Paper

By JOSEPH LEDWINKA[1]

ALL DESIGNERS of motor-cars have been striving to reduce the over-all height to the minimum. On a rear-wheel-drive car this height can be calculated from the top of the differential housing in the case of a sedan, in which the rear seat is directly over the rear axle. Generally, the over-all height can be brought down to approximately 69 or 70 in. In a front-wheel-drive car we can reduce this height considerably. A car was exhibited at the Paris Salon in November, 1929, that was only 54 in. in over-all height. Only a contortionist could safely enter this molehill on wheels. Had the car been placed alongside the curb, even the contortionist would have had to give up.

In a car to be built in quantities suitable for the majority of people, it is necessary to strike a happy medium. If the chassis is built for a 9-in. road-clearance and if the side frames are 7 in. deep and the floorboards are laid directly on the frame, we have a height from ground to top of floorboard of approximately 17 in. Then, if we make the seat height 12 in., with 37-in. headroom and $1\frac{1}{2}$ in. for the roof, we have $67\frac{1}{2}$ in. If we make the roof thickness from the centerline on top to the door opening of the very thinnest, say $3\frac{1}{2}$ in., and assume the height of the curb as 8 in., it is necessary for the passenger to stoop down to 56 in. to be able to enter. These figures do not include a running-board, as it would seldom be used. But, a running-board, even if not used, is advisable on account of spray from the wheels.

I regard this figure of $67\frac{1}{2}$ in. as the minimum height a car should be to be comfortable of access. It would be possible to reduce the height to 65 in., but it would be far better to take advantage of the low floor to give more headroom and keep the over-all height as at present in rear-wheel-drive cars. The dimensions given refer to sedans; roadsters or coupés can be made lower, as is usual on rear-wheel-drive cars.

The present tendency is for wider bodies to seat three persons comfortably on the rear seat. Wheel treads have been increased to 59 in. in the United States. Assuming 6-in. tires and a wheelhouse clearance of say 3 in., and assuming that the wheelhousing is of sheet steel, we have an inside width between wheelhousings of 47 in. Assuming the trim pads being directly against the housing, we have approximately another inch, giving an inside width between trim pads of 45 in., which would be just about enough to seat three.

If the chassis is wide and flush on the outside of the wheelhousing and has, say, a 2-in. flange, we can build an offset in the cushions and bring the rear-seat pan somewhat below the top of the frame at the kick-up as far as clearance of the differential housing in rear-wheel-drive cars will allow. On front-wheel drives we can bring the pan down even with the bottom flange, increase the height of the seat springs and make a more comfortable cushion.

Besides the advantage of better appearance of the lower over-all height, we have the advantage of lowering the center of gravity, which will add to the steadiness, reduce sidesway and, in general, improve the roadability of the car.

Wind resistance is an important factor in the height of the car. Every inch less on top adds mileage per hour. The density of the onrushing air is greatest on top.

Front-wheel-drive cars are necessarily of long wheelbase, and we have to economize in leg-room in the body to offset this disadvantage as much as possible. Chassis engineers will have to do some close figuring to reduce the length of the power unit; possibly the adoption of a V engine would help a great deal.

The absence of humming noise from the rear axle is an advantage, but muffling the noise at the front is a greater problem, and the chassis engineer must endeavor to eliminate vibration and transmission-gear noises.

Another advantage is the absence of the gearshift lever projecting through the floor. If the emergency-brake lever is placed against the side of the body, there will be no obstructions and it will be possible to seat three passengers in front comfortably if the body is kept wide enough there.

In general, I would say that on front-drive cars the body designer has a great opportunity to create harmony and beauty of lines, especially for custom jobs.

THE DISCUSSION

R. I. SCHONITZER[2]:—The company with which I am connected has had no difficulty in lowering the over-all height of the front-wheel-drive design 4 or 5 in. below the conventional type while still providing as much head-room as in rear-wheel-drive cars. The construction is very similar to that of bodies for rear-wheel-drive cars, although we have some deviations, such as the absence of the rise in the rear sill because of the elimination of the kick-up in the chassis frame. That enables us to provide for a lower seat, which contributes

[1] Service manager, Edward G. Budd Mfg. Co., Philadelphia.

[2] M.S.A.E.—Body engineer, in charge of body engineering, Auburn Automobile Co., Auburn, Ind.

to a lower center of gravity and affords more comfort. The lowering of the center of gravity, in the case of the front-wheel-drive car, pertains to both chassis and body.

The statement has been made that passengers prefer to ride in rear-wheel-drive cars on account of greater visibility, but there should be no reason why we should not have just as favorable visibility in the front-drive car. The factors pertaining to vision can be about the same, except that in the case of the front-drive car we have a lower center of gravity and the passengers' seating position is lower.

GEORGE J. MERCER[3]:—I think that the full advantage of having lower bodies with the front-wheel-drive cars will probably be utilized more particularly for the sport and open types of body. I heard yesterday of a body on a conventional-type chassis that was made so low that a lady struck her back when entering the door. I know that some of the closed bodies on front-drive cars have the door coming all the way down to the running-board and the door could not be opened when the car was driven up close to a curb about 8 in. high.

GEORGE L. McCAIN[4]:—I would like to mention the possibility of leaving the top of the car near its present height and perhaps leaving the seat as it is and obtaining greater comfort for the passengers by lowering the floor. Incidentally, that would overcome the disadvantage that the distance between the seats is less in the front-drive cars.

Tendency to Eliminate Running-Boards

CHAIRMAN T. J. LITLE[5]:—Mr. Ledwinka said that he doubts if the running-board can be eliminated; he would like to have it to protect the body. Perhaps flaps could be used for that purpose. It would be an advantage, it seems to me, to eliminate the running-boards, thereby saving weight and expense.

MR. MERCER:—I think the tendency will be to eliminate the running-board, but if the car floor is very low and the door extends down to the bottom of the side frame, it will not be possible to open the door when the car is driven up against a fairly high curb.

JOSEPH LEDWINKA:—I found out many years ago that if a car had two steps and no running-board the paint could not be kept on the rear fenders; they were always cut bare to the steel by gravel flying against them. I put a running-board on and that did away with all that trouble. The front wheels of a front-drive car drive the gravel past the end of the fender along the sides of the body and front of the rear fenders and it is surprising in what a short time the paint is worn down to the steel. The mud spray will also go all over the body. Therefore it is much better to use full-length running-boards.

CHAIRMAN LITLE:—Is it possible to get a better rear seat and a greater depth of cushion with this type of body, where you do not have to contend with the large-diameter rear-axle housing?

MR. LEDWINKA:—Yes.

CHAIRMAN LITLE:—I have seen some seats with almost no springs in the middle, and arm rests were provided because there were no springs to sit on. I think we have an advantage in this respect with the dead axle.

Body Stiffens Chassis Against Torsion

QUESTION:—Has anyone experienced a shifting of the center of strain on the front-drive car, which we all believe to be about at the roof rest of the No. 1 pillar? I think it is commonly known as the greatest point of strain.

MR. LEDWINKA:—If the body is fastened to the outside of the frame of a light chassis, the body strengthens the chassis. We have made torsional tests on the frame with the body in place but not bolted, and then with the body bolted to the chassis. The bolted-on body makes the chassis very stiff; it twists where the front bolt comes, but that is hardly perceptible. We have had no trouble from that source when the chassis was made right.

We find trouble with the chassis in almost every make of car. One breaks in one place and another somewhere else. We have to study the chassis and sometimes make it stiffer. A car should have a chassis with a stiff back that will not twist. It was almost impossible to put the body on some that I have seen without having body troubles. If a front-drive chassis is stiff it will not give any trouble, as far as we know.

LYLE K. SNELL[6]:—There has been some agitation from time to time about building bodies without a chassis frame. I have been in favor of putting a deep frame under the body that will stop all distortion. It occurs to me that some builders who have been designing bodies without frames might have an opportunity, with the elimination of the propeller-shaft and rear-axle housing, to turn the cart around. Somebody who has plenty of patience and money might spend some of it on that kind of a car and get somewhere with it. I do not think it could be made practical on a rear-drive job. From what Mr. Mercer said and some of the things I have seen, it looks as though some designers would like to move the road down to get the center of gravity lower. I think you can go too far with that.

HERBERT CHASE[7]:—The point that Mr. Snell made is one that ought to be stressed much more. As I see it, one of the chief advantages of the front-wheel drive is that it gives the body designer a much freer hand, assuming that the chassis engineer will design the frame to fit the body, which he can do very well when the rear axle becomes merely a trailing axle and can be "cranked" as much as desired. By changing the design of the frame, it should be possible not only to afford a better support for the body but to realize a lighter over-all weight than is possible with the conventional car. Some unsatisfactory compromises have to be made when you use a rear axle with a large differential housing and have to kick up the frame above the rear axle.

One thing I wish body designers would do, and I am not at all sure that they cannot do it on a front-drive car, is to lower the hood to some extent, at least enough so that short people can see over the lower edge of the windshield. I have given up hope of ever again being able to see a front fender from the driver's seat.

[3] M.S.A.E.—Detroit.

[4] M.S.A.E.—Research engineer, Chrysler Corp., Detroit.

[5] M.S.A.E.—Consulting engineer and industrialist; director of engineering, Holley Carburetor Co., Detroit.

[6] M.S.A.E.—Eaton Axle & Spring Co., Detroit.

[7] M.S.A.E.—Associate editor, ***American Machinist* and *Product Engineering***, New York City.

Front Noise May Be Less Objectionable

CHAIRMAN LÍTLE:—The bane of the production man's existence has been to produce cars with quiet axles. It seems to me that a noisy axle in the front end would be less objectionable than one under the body. Noisy axles will telegraph vibration, as we call it, to the transmission, causing us to think that we have a noisy transmission. Also, propeller-shafts whip and shake the whole body. Sometimes transmissions are very noisy. Those located under the body are more noisy and objectionable than the ones located in front.

MR. LEDWINKA:—Our experience is that noise in the rear axle is more noticeable by the passenger in the rear seat, whereas, with front-wheel drive, the driver hears the noise more. It is surprising how the gear noises will telegraph through the body, and how the cowl, like the horn of a radio, will amplify them. We had to overcome that by going at the gears in the proper way.

CHAIRMAN LÍTLE:—Have you had trouble from propeller-shaft whip? That shaft is difficult to balance. Is a pair of short propeller-shafts in the front less objectionable from the standpoint of body vibration?

MR. LEDWINKA:—Yes. We have had more trouble with the long shaft, which sometimes is not centered properly.

MR. SNELL:—One phase of sound transmission that I think has not been considered is that sound travels down-wind. When air currents are traveling through the body fast they may carry front-end noise away from the driver to those in the rear seat.

Interference with Driver's Vision

H. M. JACKLIN[8]:—Mr. Chase's idea about lowering the hood and windshield so that the short driver can see where he is going brings up the point that designers of the front-drive cars have a little difficulty getting enough radiator capacity. Consequently, the radiator must be high, since there are definite limits as to width.

Another point in driving a front-wheel-drive car is that considerably more gravel and sand are thrown around, particularly on curves. How is the designer going to put on a fender that will protect the people in the car itself?

[8] M.S.A.E.—Associate professor of automotive engineering, Purdue University, West Lafayette, Ind.

A MEMBER:—The radiator is usually mounted over the front axle, and the addition of the machinery to the front axle makes it impossible to place the radiator low. Also, it has to be high because of the narrowness of the radiators. The result is that the radiator is likely to be more expensive for the same horsepower because it is inefficient, and the extra thickness makes it necessary to use the construction that is employed.

MR. SCHONITZER:—I compared the height on our Cord front-wheel-drive car with those of half a dozen rear-wheel-drive cars of similar horsepower and found that our radiator was lower; that is, the height of the top of the radiator from the ground was less than in the cars referred to. The frontal area of the radiator is a factor to be established on the basis of the needed cooling-capacity, and for this reason we selected cars of similar engine capacity for comparison.

CHAIRMAN LÍTLE:—How does the radiator on your front-drive car compare with that on the rear-drive car of the same power?

MR. SCHONITZER:—We should have no difficulty in cooling the engine on either car. Of course, some limitations are imposed upon the design by the location of the axle, but we have not found it difficult to design around these factors. In our comparisons with several cars of similar engine capacity we found that in some of these cases the radiator on our front-drive car was 3 in. lower than on the other cars. In these instances we calculated the driver's angle of vision, as we wanted to know to what extent the driver's vision could cover the field in front of the car, and we found that our front-drive car affords a favorable condition. The intersecting point of the driver's vision with the ground line in front of the car on our front-wheel-drive cars is 30 ft. at the center line of the radiator and 12 ft. at the center line of the left front fender.

MR. LEDWINKA:—The design of the Cord car has something to do with that. We had some trouble at first. The body is low and the driver must see over the radiator and front fenders. Not much can be done about it, as little room is left for the radiator after all else goes in. The windshield is low, everything is low, so the driver cannot see anything within about 50 or 100 ft. in front of the car. The problem is difficult; you must have an efficient radiator that will fit and that is economical in surface for that purpose.

Weight Saving by Structural Efficiency

(*Concluded from p.* 469)

tailing. We should also know the weight of structure of competitive ships. Up to now figures on the weights of different wing-constructions, fuselages, landing-gear, tail surfaces and similar parts were not available in any book or magazine. If the designer has not kept for his own use a complete detailed record of such weights from previous ships, he is absolutely in the dark. Seldom can we calculate and design in all details two or three different systems of structure for one ship, which would enable us to make weight calculations for all these types before selecting the mostefficient all-around design. However, we can estimate closely influences of modifications if the weights of the original structure are known.

A Valve-Clearance Indicator

By Ferdinand Jehle[1]

Cleveland Section Paper

Illustrated with Drawing, Photograph and Charts

ONE of the major troubles that can be encountered with a valve mechanism is the change in tappet clearance. All valve-lift diagrams are laid out for a certain tappet clearance. If this clearance changes, the diagram will change. If the clearance is increased a great amount, the tappet will come into contact with the valve-stem at a velocity much higher than was intended and noise and wear will result. Should the clearance decrease a great amount, the valve may even be kept entirely off its seat, which certainly will result in a reduction in power and in valve-burning, because of leakage of the burning gases past the valve.

That the tappet clearance will vary as the engine speed and load conditions vary is to be expected, since, as the engine becomes hot, all of the parts do not reach the same temperature at the same time and therefore do not expand equally. To predict just how this clearance will vary is very difficult; therefore, to make a study of it, a special instrument called a valve-clearance indicator was designed to measure tappet clearance accurately on an engine while running.

Above in Fig. 1 is a diagrammatic sketch of this instrument in use on an overhead engine, showing the important parts in some detail. A section of the valve push-rod has been cut out and the valve-clearance indicator inserted in its place. The construction of this indicator is shown in the sectional drawing below in Fig. 1. A hollow member, *a*, has a keyway cut through it. Member *b* fits snugly but slidably in *a*, and a key, which is attached to *b*, fits nicely into the keyway of *a*. On the flat portion of *a*, adjacent to the keyway, is engraved a scale, while a vernier is engraved on the key, as seen in Fig. 2.

When the push-rod is inserted in the engine, a weak spring takes up the entire tappet clearance. The amount of this clearance is shown below in Fig. 1. As the valve opens, the light spring is compressed, allowing *a* and *b* to make contact and open the valve. As soon as the cam follower is again on the base circle, the light spring takes up the tappet clearance. If the clearance does not vary, the reading of the vernier will always be the same; but, if it varies, this reading will change, and the change in reading is the change in tappet clearance.

Arrangement of the optical equipment for reading the scale is shown above in Fig. 1. Light from a suitable source, such as a projection lamp, is thrown on the polished surfaces of the vernier and scale, which reflect it into a telescope that is focused on a screen. An enlarged image of the vernier and scale is therefore visible on the screen.

The reading of this instrument with the engine running is fairly easy. The engine is its own stroboscope, because the valve is on its seat twice as long as it is off its seat. At any speed above, say, 200 or 300 r.p.m., the image on the screen appears to stand still. The effect of load, water temperature, and what not, on the tappet clearance can thus be very easily studied at any engine-speed. This particular instrument has been used at engine speeds from 400 up to and including 2400 r.p.m.; in fact, the higher the speed is, the easier the reading becomes, because the image is more steady. Although the valve-clearance indicator has been described here as installed on an overhead-valve engine, it has been used just as successfully on L-head engines.

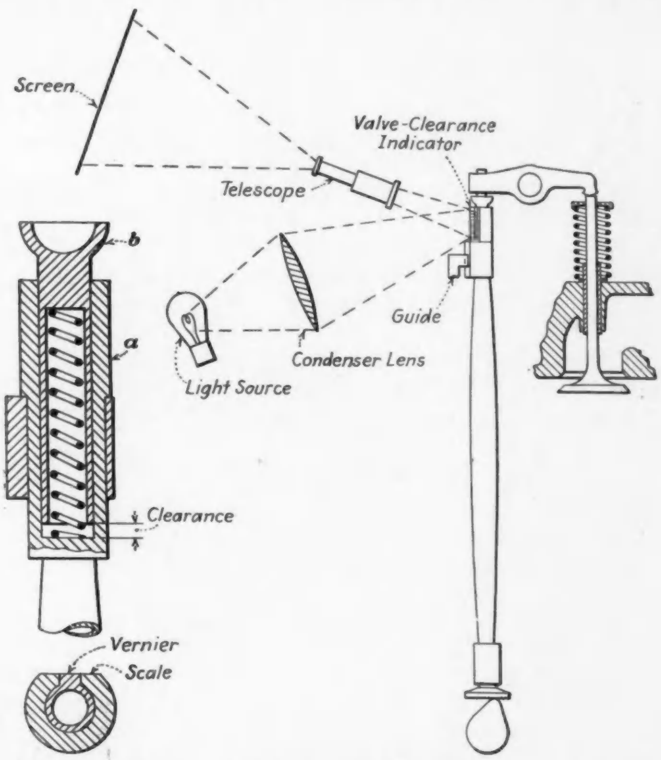


FIG. 1—ENLARGED SECTION OF INDICATOR AND DIAGRAM SHOWING METHOD OF ITS USE

Member *a* Receives Member *b*, Which Has a Longitudinal Key That Slides in a Keyway Cut through *a*. A Scale Is Engraved on the Flat Polished Reflecting Face of Member *a*, and a Vernier Is Engraved on the Face of the Key of Member *b*. A Light Spring Takes Up the Clearance in the Indicator, Which Is the Exact Clearance of the Tappet. Variations in the Tappet Clearance Alter the Clearance in the Indicator and Are Shown on the Scale. The Indicator Is Inserted in a Cut-Out Portion at the Top of the Valve Push-Rod and Light Is Concentrated on the Scale by Means of a Lens. The Mirror-Like Face of the Indicator Reflects the Light to a Telescope, Which Projects the Enlarged Image of the Scale upon a Screen, Where It Can Easily Be Read. In Operation at Any Speed, the Engine Acts as a Stroboscope, the Valve Remaining on Its Seat Twice as Long as It Is off Its Seat and the Image Appearing To Remain Stationary at Engine Speeds in Excess of 200 or 300 R.P.M.

[1] M.S.A.E.—Research engineer, White Motor Co., Cleveland.

Fig. 2 is a photograph of the indicator, the two views showing the vernier member in different positions, thus illustrating the working of the key. One very important fact must not be overlooked; the scale and the vernier must have a mirror polish.

The object of this paper is to describe a piece of apparatus and not to discuss results obtained by its use. Nevertheless, two charts showing some more or less typical results obtained by the use of a valve-clearance indicator are included.

Variations in inlet-valve clearance, as shown by this indicator, at 300 r.p.m., with the engine idling;

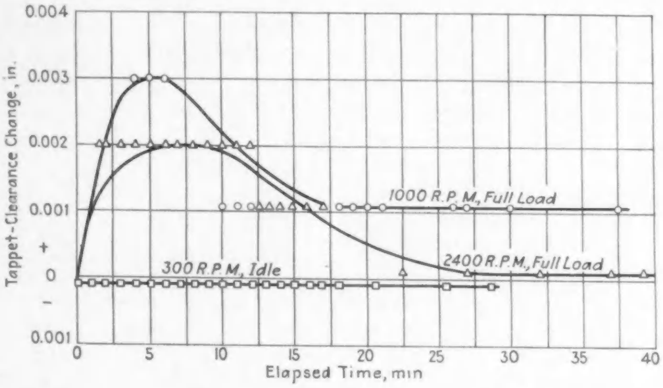


FIG. 3—INLET-VALVE-CLEARANCE CHANGES AT THREE ENGINE-SPEEDS, AS SHOWN BY THE INDICATOR

at 1000 r.p.m., full load; and at 2400 r.p.m., full load, are plotted in curves in Fig. 3. The tappet-clearance variation is shown in thousandths of an inch on the ordinate scale.

Exhaust-valve clearance variations are similarly plotted in Fig. 4 for corresponding engine-speeds and loads.

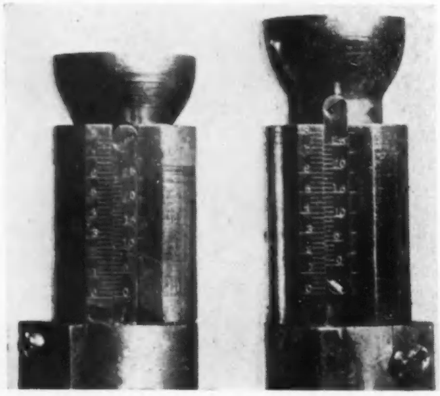


FIG. 2—INDICATOR, SHOWING SCALE WITH TWO POSITIONS OF THE VERNIER

At idling speed the inlet-valve tappet showed no reduction of clearance throughout a 30-min. run; at 1000 r.p.m., full load, it showed an increase of 0.003 in. after a run of 5 min. and then dropped to 0.001-in. increase after $17\frac{1}{2}$ min.; and at 2400 r.p.m., full load, it showed an increase of 0.002 in. in the first $7\frac{1}{2}$ min. of operation, then dropped to 0.001-in. increase during the next 8 min., and finally to almost zero after about 27 min. of operation.

The exhaust-valve clearance decreased at idling speed by 0.002 in. after 9 min., then remained stationary at that value; at 1000

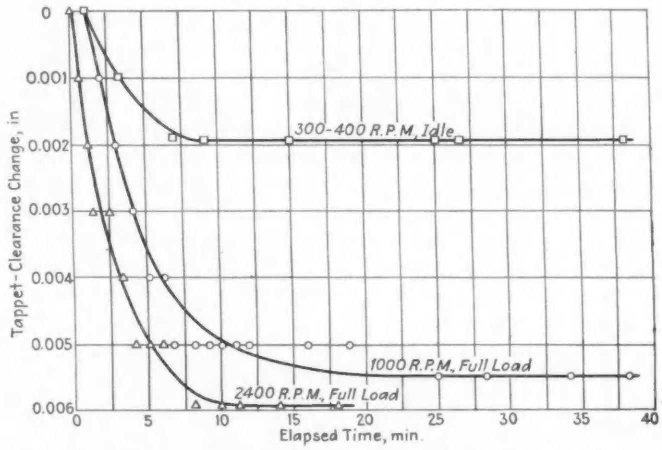


FIG. 4—EXHAUST-VALVE-CLEARANCE CHANGES AT SPEEDS CORRESPONDING TO THOSE IN FIG. 3

r.p.m., full load, it decreased by 0.005 in. in the first 10 min. of operation and by 0.0055 in. after 20 min. and became constant; at 2400 r.p.m., full load, the normal clearance decreased by 0.006 in. in the first 10 min., then remained constant at that value.

American Passenger-Car Gearsets

Discussion of Herbert Chase's Semi-Annual Meeting Paper[1]

F. STRICKLAND[2]:—I have read with great interest the discussion at the Society's meetings on gearsets and gears and think that the following notes from an English point of view may be of interest. I own two American and one English car and am writing from my own experience and that of my friends.

The tendency of recent years has been for European cars to be fitted with four speeds and American cars with three, the American car usually having a larger engine, with the idea that the cars should take pretty well the same hills on their top speed that the European cars take on their third. The top-gear ratio is not very greatly different in the European and the American cars, being usually, for the moderate sized car, about 4.5:1, with wheels about 30 in. in diameter. The English cars, at all events, usually have considerably quieter gears than the American cars, even in the case of good quality American cars selling at more than $2,000 in the United States.

Comparing these two types in practical driving, there is no doubt that the bigger engine of the American car has distinct advantages in that less gear-changing is required and better acceleration and hill-climbing are obtained on top gear. The fact that the lower gears are noisy matters little, considering how little they need be used.

Large Engine and Three Speeds Uneconomical

On the other hand, both technically and practically, a great deal of the possible advantages of the larger engine is lost because the car is under-geared for most of its running. If the engine and gear are such that the car will go up a hill of 1 in 10 on top gear, it follows that on the level the engine is developing only one-fifth or less of its full mean pressure in the cylinders. This is a very uneconomical way of running a gasoline engine as regards both fuel and oil consumption and repairs. The wastefulness in fuel of running throttled with low compression is obvious. A consideration of the relative inertia and explosion pressures at high revolutions and low compression will also show that the bearings are being worn, not by explosion pressures which propel the car, but by inertia pressures which do no useful work. In the American engine having larger cylinders than the European, all the troubles due to inertia forces are increased.

Some years ago I had a seven-passenger American car with an eight-cylinder V engine of 282-cu. in. piston displacement and weighing, without passengers but with fuel, water and oil, as run on the road, 3900 lb. The gear ratio was 4.6:1 and the wheels were 32 in. in diameter. I geared this car up to 3.5:1 and found that, for ordinary English running, it was greatly improved. The engine revolutions were reduced at a given speed in the ratio of 3:4; that is, at 42 m.p.h., from 2000 to 1500 r.p.m. The gain in quietness and comfort was enormous, while the reduction in wear was also great.

As the inertia forces increase as the square of the speed, and rubbing speed as the speed, theoretically the wear due to inertia increases as the cube. The wear due to inertia with the higher gear is therefore thoretically considerably less than one-half. Fuel consumption was, of course, improved. However, the essential point, from my point of view, was the greater comfort.

Of course, there was slightly more gear-changing, but, even with the higher gear-ratio, 98 per cent or more of the running was on top gear. The fact that the whole gear-ratio was raised made the second speed much more useful than it had been, and it was always used for quick acceleration.

Limit to Raising Three-Speed Ratio

A limit to raising the gear ratio with the conventional American transmission is that the first-speed ratio is raised and there may not be enough margin for starting with full load on a very steep hill. I never had any real difficulty with this, but with seven people up and a hill of 1 in 4, the car was not easy to start from rest. The ratio between top and bottom gear was 3.15:1, and from top to second, 1.8:1.

A car of these proportions with a top gear of 3.5:1 and gear ratios of 1.8 and 3.6 for the second and first speeds would be, to me, very satisfactory if the second speed were reasonably quiet.

Several speakers have suggested that top-gear running and quietness can be secured simply by increasing the engine dimensions and gearing up. There is a certain amount of truth in this, but the objection still remains that the engine is running very much throttled the greater part of the time. Thus, if we increase the cylinder size of the car I have described to 365 cu. in., the engine will then drive the 3.5:1 gear up the same hill as with 282 cu. in. and 4.6:1 gear-ratio. But with 365 cu. in. I should prefer a 2.75:1 gear ratio and still greater quietness and durability, with lower fuel consumption, even though I changed gear a little oftener. In fact, all the same arguments apply.

The objection to the high gear-ratio and the three-speed transmission is that the gaps between the gears are large. The ideal is, to my mind, without doubt a four-speed transmission with first, second and third gear-ratios the same as the usual American low, second and high, with a fourth speed 25 or 30 per cent higher. The third in this case should be a really silent gear. I have driven such a car with internal-gear third speed and a 3.9:1 top speed and it seemed to me very satisfactory.

One point to be remembered is that it is easier to make a bevel gear quiet with a small ratio than with a big one. However quiet the 4.5:1 bevel gear may be when new, it is not really quiet when a little worn, as can be seen by comparing it with a worm. The third speed of

[1] The paper was published in the S.A.E. JOURNAL, June, 1930, p. 727. The author is associate editor of *American Machinist* and *Product Engineering* and is a Member of the Society. Written and oral discussion was printed in the August, 1930, issue of THE JOURNAL, p. 163, and the accompanying written discussion was received subsequently.

[2] F.M.S.A.E.—Boynton Hall, Bridlington, Yorkshire, England.

such a car should therefore be as quiet as the normal top speed, the slight extra noise of the internal gears being compensated for by the quieter bevel gear. The top speed should, of course, be much quieter than the usual top speed. This seems to me to obtain in practice.

The internal-gear transmission appears complicated but could possibly be simplified. Whether it is commercially worth the extra cost remains to be seen, but I should certainly be willing to pay the extra cost myself.

External helical gears should not cost very much more than the ordinary type and may be quiet enough for all ordinary purposes. I notice, however, that the Reo and Pierce-Arrow companies put the helical gear in the middle of the gearset. Two English makers at least put the third-speed gear at the back of the case close to the back bearing, which seems much better, as it avoids noise due to springing of the shaft.

Direct Drive on Third or Fourth?

Two points are worthy of notice. One is the direct third and over-geared top speeds. This was tried in England by several makers, including Rolls-Royce, about 20 years ago but was abandoned in favor of direct drive on fourth speed and indirect third. The theory of direct drive on third is that the third gear will be the usual running gear and the over-geared fourth will be used only for exceptional work on a long straight road. In practice, unless the top gear is very high indeed, it will be used for more than 75 per cent of the running and therefore is technically the one that should be the direct gear.

I have given my experience of gearing-up an American car of average proportions to 3.5:1. If this car had been geared up to 3.0:1 or even 2.5:1, more than 80 per cent of the running would still have been done on top gear, and it is not within practical policy to make the top-gear ratio as high as this unless more than four speeds are provided.

There are other difficulties. It is more difficult to make the bevel gear quiet with a high ratio and to make transmission gear quiet when gearing up than when gearing down. Altogether, the over-gear seems very inferior to four speeds with direct drive on top gear.

An arrangement made on some Continental cars is a separate gearbox in addition to the ordinary three-speed transmission and mounted separately. If this is used in conjunction with the ordinary three-speed transmission and the ratios are suitably chosen, it will theoretically give six speeds. In practice, the difficulty of gear-changing makes this impractical and it is actually used as an overdrive gear giving four speeds. It seems a very complicated way of getting the extra gear and, if arranged for an overdrive, has all the mentioned disadvantages.

My conclusion, therefore, is that my ideal is a four-speed transmission with direct drive on top gear and a really silent third-speed gear, the first, second and third-gear ratios being about the usual low, second and high of the conventional American car and the fourth gear about 30 per cent higher. If the expense and complication of this are too great, I would have a three-speed transmission with the first speed not greatly higher than is the present standard American practice, but both the second and third about 30 per cent higher. This means, of course, a gearset with a considerably higher ratio between the bottom and top gears than is usual practice. This gearset should have a reasonably quiet second speed.

Engines Having the Cylinders Parallel to the Shaft

(Concluded from p. 412)

Altogether, 90 crankless units have been built and a broad engineering foundation has been laid for the correct design of machines for any purpose. As means for the interconversion of reciprocating and rotary motion, this mechanism offers numerous and important advantages in nearly every field. As an automobile engine, it is the direct answer to the prayer of the front-wheel-drive designer, since it puts a greater proportion of the vehicle weight on the front wheels and permits shortening the present hood by one or two feet. Because of greater compactness, inherently easy machinability of the parts, and the possibility of reducing the weight some 30 per cent below the comparable crankshaft unit, it offers also, when designed for production, the possibility of an appreciable cut in present production costs, low as they are, particularly if combined with the successful rotary valve.

The Michell engine is a real engineering achievement; but it should not be judged by what has been done with it, as though it were now in its ultimate form. Millions of crankshaft units have been built for every Michell engine in existence; thousands of minds have worked to perfect the crankshaft mechanism for every single mind that has been thinking of the crankless. Existing units should be used only as visible evidence of the practicability of the Michell engine mechanism and also as a basis for the vision of what is to come.

For Student Engineers Only![1]

A LOVELY lady, visiting the City of Washington not long ago, presented herself at the Bureau of Education on behalf of her darling daughter. "I'm here," she explained, "to choose the very most select finishing school for Gwendolyn. You see, we're very anxious to have her well macadamized."

What term, we wonder, could better describe the surface treatment acquired by our Gwendolyn? To become macadamized is certainly not your aim as you pursue your engineering studies. Had you wished merely to spend four easy years of campus comedy, you would not have cast your lot in engineering. Perhaps it is safe to assume, then, that you are an engineering student, first, because your aptitude and inclination call you to this profession; second, because you aim to acquire the best tools for your engineering career in the form of knowledge, contacts and habit systems that are sound and true; and, finally, because you are determined to make of yourself a man of well-balanced development whose mark in the world will not be a question mark.

Your heaviest assignment is engineering yourself! Your classmates, Bill and Charlie, have the same problem, so we can possibly discover a few essential facts by picking these men to pieces. Judged by human standards, they enter the University with approximately equal shares of nature's endowments. How they use these endowments remains to be seen.

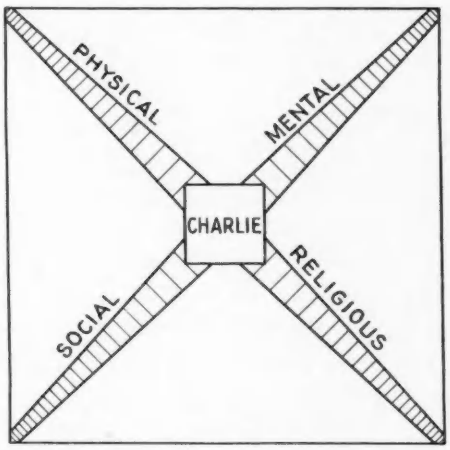
How Bill Starts His Career

Bill starts right off to prove that an education is the only thing in this world to be paid for, then left behind the counter. He beholds those four years that lie before him as a splendid opportunity to have a good time amid pleasant surroundings, and, most important of all, with very little effort. Bill is a snob for no good reason; his nose carries very high. To be sure, he has the looks, with his fine athletic figure and a marcel wave that's nobody's business. Quite naturally the flappers cast longing glances as they behold him in sweat shirt and corduroys swinging niftily along on a Saturday afternoon. Saturday afternoons and Sundays, in fact, are our friend's busiest periods. Monday morning marks the beginning of another week of annoyance with classes and assignments that do nothing but spoil a lot of valuable time. Professors are noisome pests who display neither understanding nor sympathy for Bill.

Too proud to fight and with no real objective to shoot at, Bill emerges from his four years of education with a set of grades that barely get him by; but he has acquired the best little list of cross-indexed telephone numbers of any man in the class. Although he considers himself a very crafty fellow to have fooled the faculty, he little realizes that he has spent four priceless years as his own worst enemy. So, home he goes, hangs his diploma on his bedroom wall, partakes of the fatted calf and goes off at his Dad's expense to spend a couple of months recuperating from the hard, relentless grind of nine petting parties a week.

Charlie's Introspective Analysis

Suppose we leave Bill long enough to go back and take a look at his classmate, Charlie. "Serious minded but not too serious" describes him well enough. At least he knows why he has come to the University and he starts his work with a little project of his own devising, a course of Introspective Analysis. He takes account of *his* personal stock. He does a little engineering planning that involves neither least squares, hydrogen ions nor indeterminate structures. In fact, he plans to make *his* structure *determinate* by virtue of his own efforts; this structure to be that of a HE MAN, FOUR SQUARE.



Without actually going through the motions, Charlie thinks out a plan that would be somewhat like this[2]:

He locates himself in the center square and directs his development up the ladders that extend toward his goal.

Here we find our man with a good square start toward the ultimate of his career, with four broad but well defined lines of development. His personal stores of stock contain ten items which he weighs and evaluates with care, realizing that he is in a position to know himself better than his associates can possibly know him. Here are Charlie's stocks:

(1) ADDRESS AND MANNER (Do I leave a good impression? Do I talk well? Am I popular? Have I a good bearing?)

(2) ATTITUDE (Am I rational, amenable to reason in my views? Interested in my work? Optimistic? Self-controlled?)

(3) CHARACTER (Am I reliable? Dependable? Absolutely honest? Responsible? Clean? Just? Courageous?)

(4) COOPERATIVE ABILITY (Can I work with others? Am I accommodating? Loyal? Willing to learn? Tolerant? Tactful? Am I a good mixer?)

(5) DISPOSITION (Am I cheerful? Courteous? Congenial? Enthusiastic? Not conceited?)

(6) INDUSTRY (Am I a hard worker? Have I perseverance? Am I persistent?)

(7) INITIATIVE (Am I a self-starter? Do I recognize, start and develop opportunities to a successful conclusion? Am I original?)

[1] Contributed at the request of student engineers.

[2] From Purdue University Bulletin on the Personality Rating Scale and Classification of Attributes, by J. E. Walters, personnel director.

(8) JUDGMENT (Have I common sense? Observing and reasoning power? Foresight? Resourcefulness? Do I know values and the relations of things? Am I practical?)

(9) LEADERSHIP (Do I understand men and can I command their respect? Have I executive ability? Do I precede and direct men?)

(10) NATIVE CAPACITY (Am I naturally accurate, systematic, bright, alert? Can I concentrate? Do I learn readily? Have I a natural aptitude for work?)

Is Charlie Visionary?

"Visionary, impractical," some unthinking person might call Charlie, but we find him consistently and intelligently planning his work, working his plan. "How well does he succeed?" need not be asked, for we have seen many Charlies with plan and purpose who come through with colors flying. Scanning his experience at the University, we see in Charlie a well-balanced person with his share of human weaknesses, but with the will and the wherewithal to strengthen them. Socially, he stands well, he is liked; with the ladies he, too, has his moments. Mentally, he is *there*. Physically, he is well developed; he plays very passably with racket, clubs and pigskin, although the coach would not call him the Fifth Horseman. Religiously, he is a "workman that needeth not to be ashamed."

When Bill, with a fine coat of tan, reports for duty at the Kwikkleen Vacuum Sweeper factory where his father has found a position for him, he is surprised to find old Charlie already at work in the drafting room. In fact, Charlie has spent three summers with the Kwikkleen people and has fairly well established himself as a real asset to the business. The two men work side by side for a while, until Charlie is assigned to a special job in the experimental department. Bill wonders why his friend gets all the breaks.

As time passes, he has many more chances to wonder, and it seems to him that the fates stand against him. No one cares to hear his stories of one social victory after another; it appears that his colleagues place stumbling-blocks in his way and he stays pretty well chained to the drafting board. Bill little realizes that a man who is all wrapped up in himself makes a very small package. One day our friend, still high and mighty, tries to be sociable with the chief draftsman. "I passed your house last night," says he. "Much obliged," his chief replies.

When Bill has an idea that might improve the product, he is unable to make that idea effective because he has not so much as tried first to sell himself to his associates and superiors. He is a "Yes" man, does little heavy thinking on his own, talks a great deal about himself and his ability, but never comes through with anything that puts a dollar in his boss's pocket. He is a soft-soap artist and calls it diplomacy. His associates remark that "an empty vessel makes the loudest tinkle."

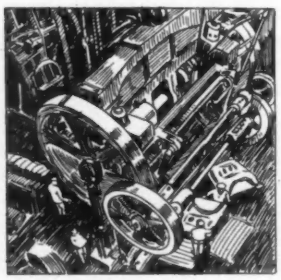
Let us not suffer longer with Bill, except to record the fact that he is a snob and marries the boss's daughter, who supports him in the manner to which he has been accustomed.

Charlie finds it very practical and agreeable to support himself. Realizing that authority is earned, not delegated, he makes it his business to earn that authority. In short, he continues to expand his degree of usefulness by a well-ordered life that marks him as a real, substantial citizen. When he meets an obstacle, he doesn't think how much faster he might progress if the obstacle were not there. He takes the obstacle as a legitimate feature of his work, just another little resistance to be overcome. Many a stumbling-block he clears away with real diplomacy, that sadly misused term. Charlie's diplomacy is of the type that involves facts and plans that are administered clearly, concisely and sincerely with no antagonizing tendency.

Greatest Attribute Is Good Sense

By virtue of his well-developed attributes, our hero achieves a high standing in the engineering profession. A broad-gage man, he never stops learning. He equips himself to sit in the front office by becoming well versed in matters of production, advertising, sales and service as well as engineering; for he well knows that, in his case, pure specialization and a narrow outlook will surely restrict the scope of his possibilities. One of Charlie's hobbies is that intriguing pursuit known as research. Although engaged in manufacturing vacuum cleaners, he delights in following the progress of pure and applied research in other lines.

Charlie's knowledge of physics turns out to be one of his greatest assets in the engineering world. But, speaking of assets, the sum total of physics, mathematics and all the other "ics" scores very weakly when compared with Charlie's greatest attribute, horse sense. So, without qualm or fear, we can leave our hero to reach the top as a regular citizen, a worthy engineer, a *man four square.*



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IF true worth is determined by usefulness, the Society's publications will unquestionably take on a new value with the appearance of a Cumulative Technical Index covering a period of 25 years, from the earliest S.A.E. BULLETIN and JOURNAL through the most recent issue of TRANSACTIONS. The preparation of such an index is going forward rapidly under the direction of the Research Department.

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Engineering Test Bases for Aircraft

TO IMPROVE the service to the manufacturer as well as the method of test work, the Department of Commerce has established engineering test bases at New York City, Detroit, Kansas City and Los Angeles for the testing of aircraft for approved-type certificates. These bases are located respectively at Roosevelt Field, Long Island, N. Y.; Wayne County Airport, Wayne, Mich.; Fairfax Airport, Kansas City, Kan.; and Municipal Airport, Los Angeles, and are now equipped and ready to function.

Similar stations are to be established at Cleveland, St. Louis, Wichita, Kan., and Oakland, Calif., and will be equipped as the necessity arises and appropriations become available.

With the four stations already set up and functioning, and with permission to arrange for tests at any of the other four when necessary, virtually all aircraft factories in the Country are within approximately 2-hr. flight of an engineering test base.

Two or more engineering inspectors will be assigned by the Department to each base, hence the aircraft manufacturer will know where contact can be made with an inspector and can arrange in advance for a definite date for a test.

The equipment at each base includes scales for determining the weight of the aircraft empty, ballast for loading an airplane for flight-test purposes, and instruments for checking qualitative flight performance.

At present, static tests are not expected to be conducted at these bases but will be made at the factories under the supervision of a Department of Commerce factory inspector. After the engineering data have been approved, the test station nearest the factory will be notified of the approval and instructed to arrange for a date for the inspection and flight test. If static tests are necessary, the factory inspector will be notified to conduct them prior to arrangements being made for the flight test. The factory will provide a test pilot, as heretofore, to work with the Department engineering inspector in conducting the flight test at the engineering test base.

The Department believes that the foregoing arrangements will be of distinct advantage to all concerned. It is another step in the decentralization program of the Aeronautics Branch for the purpose of making the inspection and test facilities of the Department more conveniently available to the industry.

News of Section Meetings

(*Concluded from p.* 391)

Experience during the last year with a valve invented by Ralph Friedl, of Oakland, Calif., was stated by Mr. Harris, and illustrations were presented and described so that the audience might have a better idea of this system of cooling the valve and scavenging the engine. In conclusion, the advantages of the Friedl valve-cooling system were summarized as follows:

(1) The cooling of the exhaust valve and its stem by refrigeration with expanding air

(2) The prevention of burning, sticking, warping and consequent leaking of the exhaust valve

(3) To make unnecessary daily greasing and servicing of the valve assembly and to obviate frequent regrinding between "major" overhauls

(4) Permitting unlimited wide-open-throttle operation without danger of damaging the the valves

(5) A thorough scavenging and clearing of combustion and exhaust-chamber of all exhaust gases after each exhaust stroke, with attending increase in power

(6) The cooling of the inner walls of the exhaust passage

(7) The prevention of a red and white flame issuing from the exhaust, due to the *complete* burning of all exhaust gases before emitting from the exhaust-passage opening, or venturi, rendering an exhaust manifold unnecessary

(8) Forced reduction of exhaust-gas pressures to atmospheric pressure *within* the exhaust-passage

(9) Accomplishment of all the foregoing features without a power-driven accessory or the additional weight, so that a saving in both weight and air resistance is effected.

T. Lee, Jr., gave a description of how the school he represents aided Mr. Friedl in the development of his idea and made tests to determine whether this system was practicable. The effects of distribution on valve life were described by L. T. Folsom, of the Caterpillar Tractor Co., in a technical manner. After the technical papers had been presented, the discussion centered on further details of the subject.

A Weekly Luncheon Meeting of the Oregon Section, Held in the Garage of the Portland Gas & Coke Co.

Oregon Section Friday Luncheons

WEEKLY luncheons in Portland are a feature of the Oregon Section's activities. These are held on Fridays in different places and afford an opportunity for the officers, members of committees and other members of the Section to meet frequently to informally discuss plans for coming regular monthly meetings and business of the Section. This helps to stimulate interest and keep the chairmen and members of the various committees spurred on to enthusiastic activity.

The luncheon meeting shown in the accompanying picture was held on a recent Friday in the garage of the Portland Gas & Coke Co., where box lunches were served. The traveling laboratory of the Standard Oil Co. of California was placed at the disposal of the members, and G. P. Texada, custodian of the laboratory and a former member of the Oregon Section, explained the exhibit of lubricating oils.

At the last preceding luncheon the officers and members present discussed arrangements for the September monthly meeting. It was reported that the speaker originally planned for could not be obtained and that arrangements had been made to have E. Favary give a talk on High-Compression Engines.

Standardization Progress

Aircraft-Engine Specifications

Minor Revisions and an Addition of One New Specification Made at Division Meeting

THE Aircraft-Engine Division of the Standards Committee met during the National Air Races and the 18th National Aeronautic Meeting of the Society in the Palmer House, Chicago, Aug. 27.

A large part of the time was devoted to the discussion of the proposed specifications on the No. 50 propeller-hub and shaft-end and on the entire proposed series of propeller-hub cones and nuts for which no specifications have ever been adopted.

No. 50 Propeller-Hub and Shaft-End

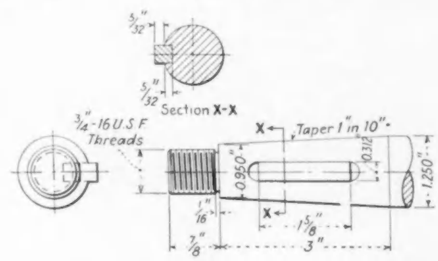
A number of dimensions on this propeller-shaft-end hub were discussed but the Division decided to postpone recommending standardization on the No. 50 hub as some trouble had been experienced in the field with this particular design. Among other things, the taper of the rear cone is now under experiment, 8½ deg. being suggested.

Propeller Hubs

The Division voted to add a dimension *Z* as an over-all dimension of the hubs in the present specifications as shown on p. 3 of the 1930 edition of the HANDBOOK and also to omit one spline from the hub drawings on the center line of the propeller blade.

No. 0 Tapered Shaft-End

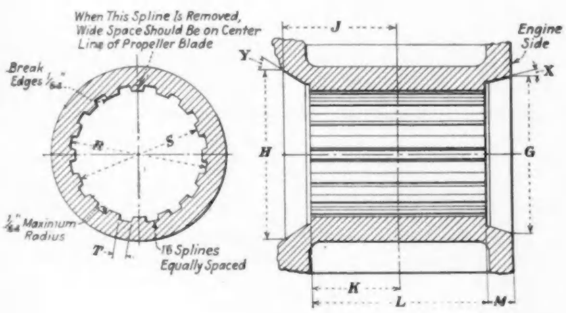
The present specifications of the No. 0 tapered-type shaft-end, as given on p. 4 of the Supplement to the 1930 edition of the HANDBOOK, show no key dimensions for this size. The Division recommended that these dimensions be added to the specifications, and as soon as the proper dimensions have been determined they will be submitted to the Aircraft-Engine Division and to the Standards Committee for approval.

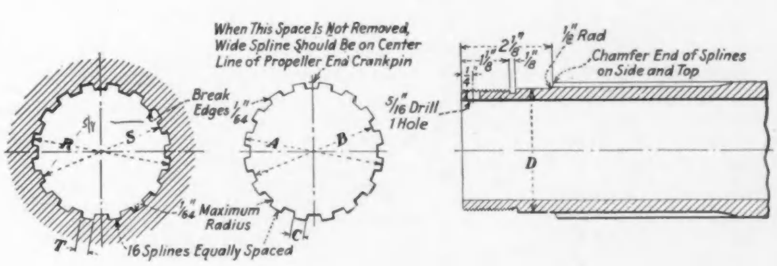


Wood Propeller-Hubs

The question of adopting specifications on wood propeller-hubs was again discussed and the Division decided to have a definite suggestion formulated as a proposed S.A.E. Recommended Practice for submission to the Division at its next meeting.

The following subjects were suggested for standardization and have been placed before all members of the Division by letter-ballot to determine the advisability and feasibility of attempting to develop specifications for these parts: aircraft-carbureter flanges, copper-asbestos gaskets and compression piston-rings. Comments and suggestions from all engineers interested in these items are earnestly invited and will be given careful consideration by the Division before definite action is taken.



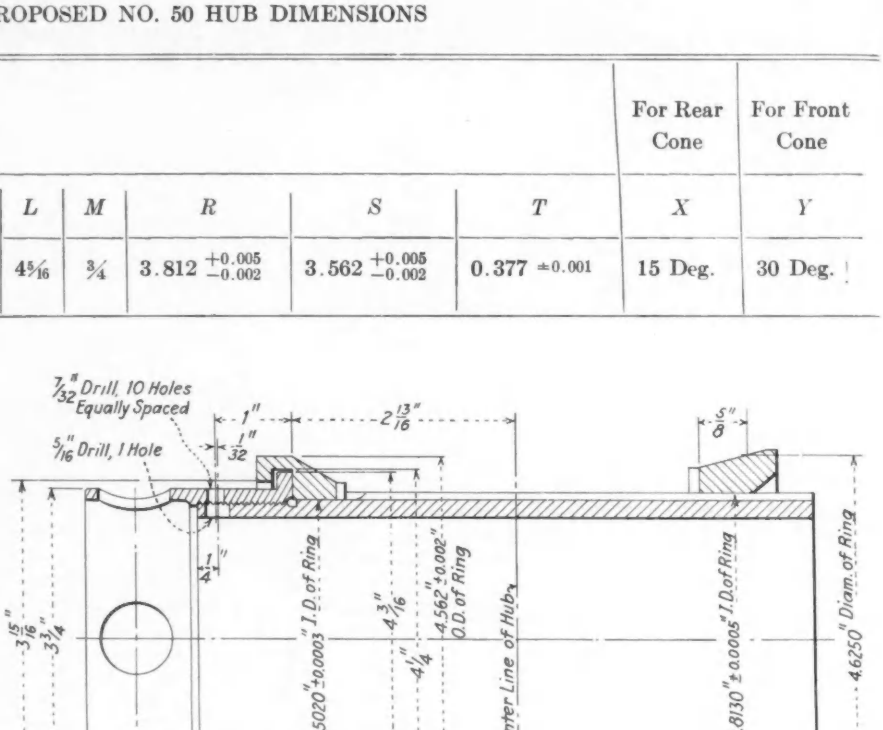


PROPOSED NO. 50 SHAFT ENDS

SHAFT ENDS					HUB		
A	*B*	*C*	THREAD	*D*	*R*	*S*	*T*
$3.804\ ^{+0.000}_{-0.002}$	3.554 Maximum	0.3750 ± 0.0008	3 7/16-12 U. S. Fine 3.381 ± 0.002 Pitch Diam.	$3.500\ ^{+0.000}_{-0.002}$	$3.812\ ^{+0.005}_{-0.002}$	$3.562\ ^{+0.005}_{-0.002}$	0.377 ± 0.001

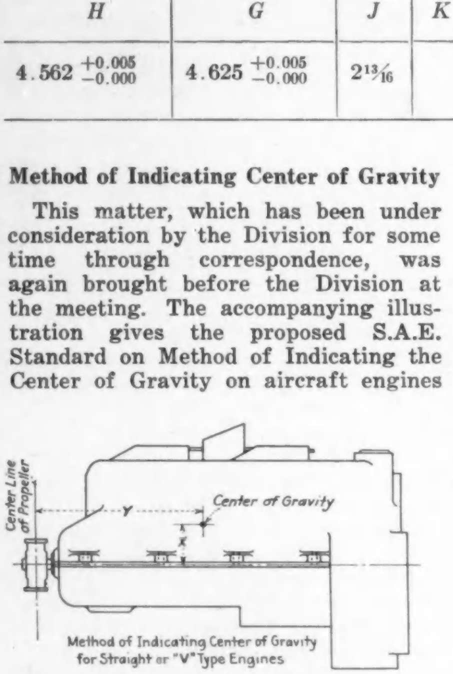
PROPOSED NO. 50 HUB DIMENSIONS

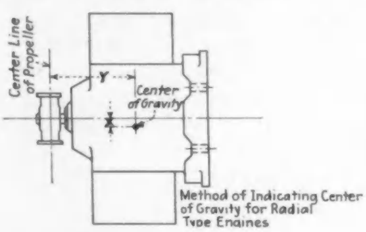
Front End	Rear End								For Rear Cone	For Front Cone
H	*G*	*J*	*K*	*L*	*M*	*R*	*S*	*T*	*X*	*Y*
4.562 +0.005 −0.000	4.625 +0.005 −0.000	2 13/16		4 5/16	3/4	3.812 +0.005 −0.002	3.562 +0.005 −0.002	0.377 ±0.001	15 Deg.	30 Deg.



Method of Indicating Center of Gravity

This matter, which has been under consideration by the Division for some time through correspondence, was again brought before the Division at the meeting. The accompanying illustration gives the proposed S.A.E. Standard on Method of Indicating the Center of Gravity on aircraft engines

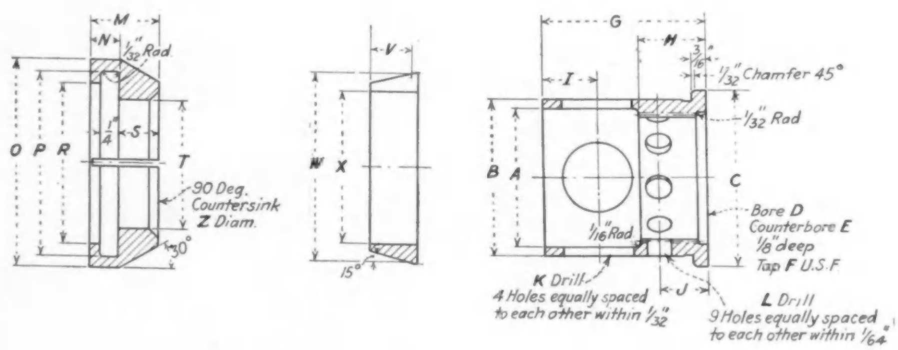




as approved by those present. This specification is being submitted to the Division by letter-ballot and if approved will be submitted to the Standards Committee in January.

Propeller-Hub Cones and Nuts

Several changes were suggested in the proposed dimensions submitted to the Division for the series of propeller-hub cones and nuts. After further study is made of this matter, a revised drawing and table will be submitted at another Division meeting for further consideration.



PROPOSED PROPELLER CONE AND NUT DIMENSIONS

S.A.E. No.	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*
10	1 13/16	2 1/16	2 5/16	1.601 ±0.002	1 45/64	1 11/16—12	2 1/8	7/8	23/32	5/8	57/64	5/16
20	2 3/16	2 7/16	2 11/16	1.976 ±0.002	2 5/64	2 1/16—12	2 1/8	7/8	23/32	5/8	57/64	5/16
30	2 3/8	2 5/8	2 15/16	2.226 ±0.002	2 21/64	2 5/16—12	2 1/8	7/8	23/32	5/8	57/64	5/16
40	2 15/16	3 3/16	3 7/16	2.726 ±0.002	2 7/8	2 13/16—12	2 1/8	7/8	23/32	5/8	57/64	5/16
50	3 15/32	3 3/4	4 3/16	3.351 ±0.002	3 9/16	3 7/16—12	2 7/8	1 9/32	27/32	1 1/16	1 1/32	3/8

S.A.E. No.	*M*	*N*	*O*	*P*	*R*	*S*	*T*	*V*	*W*	*X*	*Z*
10	29/32	13/32	2 3/4	2 7/16	2 1/8	17/32	1.6875 ±0.0005	17/32	2.500	2.001 ±0.0005	1 15/16
20	29/32	13/32	3 1/8	2 13/16	2 1/2	17/32	2.0625 ±0.0005	17/32	2.875	2.3760 ±0.0005	2 5/16
30	29/32	25/64	3.250 ±0.005	3	2 11/16	1/2	2.3120 ±0.0005	17/32	3.187	2.626 ±0.0005	2 9/16
40	29/32	13/32	3 7/8	3 9/16	3 1/4	17/32	2.8125 ±0.0005	17/32	3.625	3.126 ±0.0005	3 1/16
50	1	7/16	4 9/16	4 1/4	3 15/16	9/16	3.5000 ±0.0005	5/8	4.625	3.8050 ±0.0005	3 9/16

Nickel-Plating Information

Non-Ferrous Metals Division Considering Adoption of Data as General Information

FOLLOWING its announced policy of preparing data on various metals and methods of plating to be published in the Non-Ferrous Metals Section of the S.A.E. HANDBOOK as General Information, the Non-Ferrous Metals Division has, through its Subdivision on Zinc, Lead and Tin and its Chairman, H. C. Mougey, prepared material on nickel-plating. This material has been submitted to the Division for the taking of a letter-ballot to determine whether it shall be placed before the Standards Committee meeting in January for approval. Comments and criticisms will be submitted to the original Subdivision for consideration. If approval is indicated by the letter-ballot, the following material will be put before the Standards Committee for S.A.E. General Information:

NICKEL-PLATING

(To be published, if approved, under the heading of General Information in the Non-Ferrous Section of the S.A.E. HANDBOOK.)

Nickel-plating has been in commercial use since 1840, but there are many factors which are not thoroughly understood, and many troubles are likely to occur from time to time in nickel-plating. Chromium-plating requires careful control of the factors of composition of the bath, temperature, current density, etc., and without this control chromium-plating is impractical. On the other hand, a deposit of nickel may be obtained under such widely differing conditions that little is known about the proper combination of conditions necessary for best results.

The nickel-plating baths in commercial use differ greatly in their compositions, but most of them contain varying amounts of nickel sulphate, with

(Continued on p. 489)

TABLE 1

	Grams per Liter of Solution A	B	C
Nickel sulphate, $NiSO_4.7H_2O$	200	..	75
Nickel ammonium sulphate, $NiSO_4.(NH_4)_2SO_4.6H_2O$	..	75	..
Ammonium chloride, or nickel chloride or sodium chloride	30	15	15
Sodium sulphate, $Na_2SO_4.10H_2O$	..	..	150
Boric acid	30	15	15

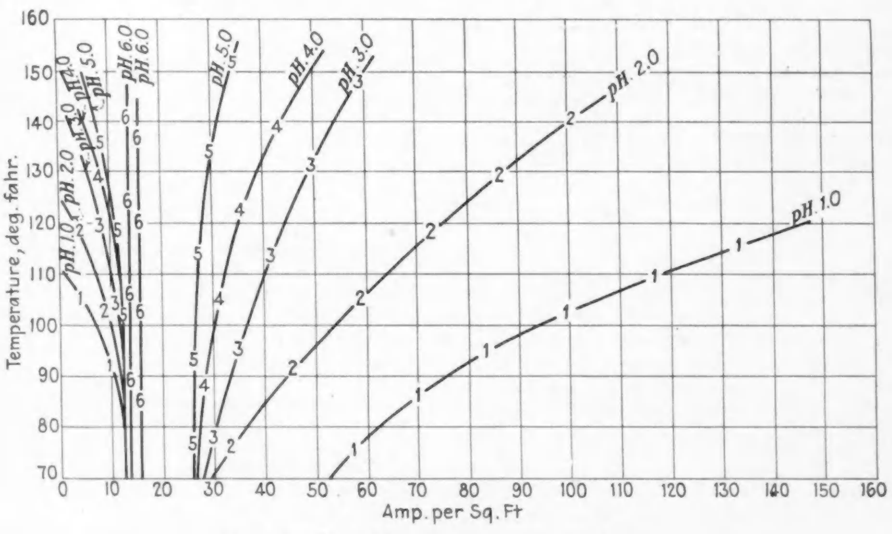


FIG. 1—FIVE-MINUTE PLATES ON COPPER

The Area Between the Two Lines for Any Given pH Is the Area of Good Deposits, not Bright. To the Left of the Left-Hand Line Is the Area of Bright Deposits. To the Right of the Right-Hand Line Is the Area of Peeling Deposits. To the Left of the Right-Hand Line Is the Area of Good Deposits for Any Given pH

Diesel-Engine Testing Forms

New Forms Being Developed by the Diesel-Engine Division for Oil Engines

MEMBERS of the Diesel-Engine Division of the Standards Committee, at their initial meeting in Detroit last April, scheduled for standardization a number of subjects relating especially to Diesel engines. Among these was the proposal to prepare a set of Diesel-engine testing forms that can be used for making all Diesel-engine tests directly comparable, in the same way that the records of gasoline-engine tests have become thoroughly standardized through the use of the S.A.E. Standard Engine-Testing Forms for Gasoline Engines. H. A. Huebotter, formerly of the Waukesha Motor Co., was appointed a Subdivision to prepare a report for consideration by the Division, which felt that this report could be modeled after the present gasoline engine-testing forms that have proved so useful for many years.

Mr. Huebotter submitted a report that was sent to the Division members prior to the Division meeting that was held in Detroit on Sept. 5.

Proposed Forms in Four Sections

The proposed forms will consist of four sections. Sheet A includes the general rules and directions for setting up and running the engine tests and for tabulating the test data. It should be noted that the method of correcting brake-horsepower for altitude will be changed to conform to that adopted by the Diesel Engine Manufacturers' Association. Specification Sheet B provides for listing dimensional and other data on the engine as well as information regarding the fuel-injection system, the air system, the lubrication system, and accessories that would normally be attached to the engine. Log Sheet C provides for test data during the engine runs, from which the curves to be plotted on Curve Sheets 1 to 4 can be developed. These curve sheets are reproduced herewith to show their general form and arrangement. The cross-sections shown are illustrative of the subdivisions that will be used in the final forms.

Curve Sheet 1 has ordinates for low and medium-speed low-power engines, Sheet 2 for low and medium-speed medium-power engines, Sheet 3 for low and medium-speed high-power engines and Sheet 4 for engines of miscellaneous speed and power.

The testing forms are published at this time for general review before the Division submits its final report to the Society at the Annual Standards Committee meeting next January for adoption by the Society and any constructive comments should be addressed to the Standards Department of the Society, 29 West 39th St., New York City, so that they may be referred to the Division in preparing its final recommendations.

S.A.E. DIESEL-ENGINE TESTING FORMS

General Rules and Directions—Sheet A

A complete engine test includes the determination at different speeds of: maximum horsepower; fuel economy at rated load, at 125, 75, 50, and 25 per cent of rated load at each of the speeds; friction-horsepower. From these data the following curves are plotted on the Curve Sheet:

(1) Max. brake-hp. to r.p.m.
(2) Max. torque to r.p.m.
(3) Max. brake m.e.p. to r.p.m.
(4) Friction-hp. to r.p.m.
(5) Mechanical efficiency to r.p.m.
(6) Fuel per b.hp.hr. at rated load to r.p.m.
(7) Fuel per b.hp.hr. at 125 per cent of rated load, to r.p.m.
(8) Fuel per b.hp.hr. at 75 per cent of rated load, to r.p.m.
(9) Fuel per b.hp.hr. at 50 per cent of rated load, to r.p.m.
(10) Fuel per b.hp.hr. at 25 per cent of rated load, to r.p.m.
(11) Brake thermal eff. at rated load, to r.p.m.
(12) Brake thermal eff. at 125 per cent of rated load, to r.p.m.
(13) Brake thermal eff. at 75 per cent of rated load, to r.p.m.
(14) Brake thermal eff. at 50 per cent of rated load, to r.p.m.
(15) Brake thermal eff. at 25 per cent of rated load, to r.p.m.

The effect of overload upon fuel consumption should be recognized in these tests as a deterrent against excessively high engine ratings. One of the limiting factors in the application of the load to a Diesel engine is the completeness with which the engine will burn the injected fuel. For this reason the rated power is closely allied with the fuel economy and ratings which lead to over-rich fuel-air charges should be discouraged.

During the entire test the engine shall be operated without re-adjustment except as required for actual changes of speed and load. Adjustments made for the purpose of improving fuel combustion or economy for particular operating conditions will not be permitted while the test is in progress.

Test runs should not be made until the engine has been run-in sufficiently to show no appreciable difference in friction before and after a run of 30 min. at normal rated speed and normal rated load.

Where test is to be made of a stock engine, all parts, accessories, lubricants, etc., must be stock. In every case, all regular equipment must be on the engine and operating (*e.g.*, fan, generator, etc.).

Before beginning any run, the engine should be brought to a condition of sustained operation under the conditions of the run and it is imperative that in every case r.p.m., brake loads, rate of fuel consumption, cooling-water temperatures, oil temperature, air draft, etc., remain substantially constant, steady and sustained throughout the run. Flash readings and tests are unscientific and misleading.

Maximum and Rated Horsepowers

(Note—Maximum horsepower as at present defined by the Diesel Engine Manufacturers Association is that at which the engine runs at normal constant speed for an appreciable time with no smoking at the exhaust and no increase in fuel consumption. Normal rated horsepower is 85 per cent of maximum horsepower.

Number of Runs

In every test, enough runs should be taken throughout the speed range so that the points therefor when plotted will indicate clearly the shape and characteristics of the curves. For horsepower and fuel-economy tests, it is recommended that runs be made at intervals of 20 per cent of rated r.p.m. A run should be made at the lowest steady operating speed of the engine. All points from which curves are plotted are to be clearly shown on the Curve Sheet.

Duration of Runs

Before any test is run on an engine, it should be run for at least one hour at maximum load at the desired r.p.m. The fractional load runs of 125, 100, 75, 50 and 25 per cent respectively should be made in the order given, allowing at least 30 min. at each load run before taking readings. Where fuel consumption is measured, the duration of tests shall not be less than 5 min. The duration of friction-horsepower tests shall not be less than 1 min. The above-stated times are minima. In most instances it is desirable to make the runs of longer duration, and it is imperative that in every case r.p.m, brake loads, rate of fuel consumption, cooling-water temperatures, oil temperature, air draft, etc., remain substantially constant and steady throughout the run.

It is recommended that the maximum allowable variation in speed during a run shall be not more than 10 per cent of the r.p.m. of the test run.

Balancing Dynamometer

Before any readings of brake load are recorded, great care should be exercised to see that the dynamometer itself is properly balanced. For the electric-cradle type of dynamometer this balancing is accomplished as follows:

The dynamometer is run idle as a motor (drawing current from the line) and a suitable counterbalance on the field frame—which should be perfectly free to turn within limits in ball-bearing trunnions—is then adjusted so that the platform scales read zero. This reading should be obtained with the dynamometer rotating first in one direction and then in the other. The reaction of the armature on the field frame will exactly balance the friction of the brushes and armature bearings carried in the field frame. With the armature still rotating, check-weights (or pieces of metal having a known weight) should be hung from the knife-edge on the dynamometer arm. If the reading recorded by the platform scales is equal to the known weight applied, the dynamometer can be considered as balanced.

Brake Loads

Readings for brake loads should be taken with accurately calibrated platform or beam scales. The connection of the dynamometer arm to these scales by means of knife-edges, calibrated spring balance and tripod or suitable linkage is recommended. Suitable counter-balances or tare loads must be accurately provided. The spring balance gives a quick approximate reading for brake load; it serves to cushion the platform or beam scales from shock and vibration. During any run, the platform or beam scales are kept balanced, and the loads registered thereby must be substantially constant and steady throughout the run.

Revolutions per Minute

Speed in revolutions per minute should be invariably taken from positively driven counters which engage at the beginning of the run and disengage at the end. The difference between the two readings, divided by the duration of run in minutes, then gives the true average speed. Tachometers, even though carefully calibrated, are not sufficiently reliable for r.p.m. readings. In connection with the speed counters mentioned, however, the tachometer may be used as an approximate check on average speed, also as an indicator of variations in speed before or during the run.

Fuel Consumption

The method recommended for measuring fuel consumption is by noting the decrease in weight of a tank from which fuel is being fed. The tank should be placed on sensitive platform scales at a proper level and connected to the fuel-supply pipe by a short length of tubing or pipe which extends into the fuel in the container and is fed by syphoning or pump suction. Weighings should be made as follows:

Set counterpoise so that scale-beam will fall just as run is started. Note the setting and the time at which the scale-beam falls. Move the counterpoise back to such a point that it will fall just before the end of the run of approximately 5 min. and note carefully the time when beam again falls. From the difference between the two times and the two weights recorded, the fuel consumption per hour can be readily determined.

The counterpoises may be successively set back for small quantities and the times noted during the progress of the run. This gives an indication of the steadiness of fuel consumption throughout the run, and in no wise interferes with the major measurements outlined in the previous paragraph.

Temperatures

All temperatures are to be given in degrees fahrenheit.

A reliable glass straight-stem thermometer should be placed near the air-inlet in order to measure the temperature of the entering air. This thermometer should be read at least three times during each run, one of these times to be at beginning and one at end of run.

Thermometer should be placed also in suitable wells or sockets, one near the inlet of the pump and another as close as possible to the water-outlet of the engine. These wells or sockets should be in pipes that run full, so that water continually circulates about them. They should be filled with oil or mercury, and careful readings taken at least three times during each run, one of these times to be at beginning and one at end of run.

In order to afford a fixed basis of comparison, it is recommended that the outlet-water temperature for engines be kept at the temperature recommended by the engine manufacturers (+or—5 deg.). Control of the outlet temperature can be accomplished by thermostat located in the outlet line or by external control of quantity or temperature of inlet water. Where thermostat or other cooling-water regulating-devices are standard upon an engine, these may be attached and operating during a test.

In every case, inlet and outlet cooling-water temperatures should remain substantially constant and steady throughout a run. It is recommended that the maximum allowable variation in cooling-water temperature shall be 10 deg. fahr.

During friction-horsepower runs it is desired to obtain the mean temperature of the jacket water. If the water is pump-circulated,

the average of the inlet and outlet temperatures may be taken. If thermosyphon circulation is used, the water will not circulate noticeably during a friction-horsepower run. The mean jacket-water temperature for such engines can be taken by inserting thermometers into the jacket space, the average of readings being taken. In every case of friction-horsepower test, the test must be made immediately after the corresponding brake-horsepower test, before the engine has cooled.

Friction Horsepower

The approximate friction-horsepower of an engine can be measured best by means of an electric dynamometer, preferably of the cradle type. The dynamometer is used to drive the engine under test at various speeds, and the torque reaction is measured. This will be in the opposite direction to that obtaining while the engine is driving the dynamometer, so that provision must be made for measuring the torque on both sides of the dynamometer, or else suitable linkage must be provided to change the direction of the pull. The test for friction-horsepower should be made immediately after the brake-horsepower test, before the engine has cooled, in order to keep the condition of the lubricating oil and the friction of the parts the same as during the brake-horsepower test, as nearly as possible. During this test the throttle of the engine should remain in the same position as for the corresponding brake-horsepower test. Compression-relief cocks should remain closed and all accessories, such as generator, pumps, etc., used during the brake-horsepower test, should be in operation. See notes on friction-horsepower runs under the various headings.

When an electric dynamometer is not available or when the electric dynamometer method is not practicable, the following method is recommended. The engine should be tested at various speeds throughout the load ranges, plotting a fuel-consumption brake-horsepower curve. The same tests should then be run with 1, 2, 3, etc., cylinders successively cut out, and the same curves plotted. The friction-horsepower can be quite accurately calculated by interpolation.

Indicated Horsepower

Approximate indicated-horsepower is obtained by adding to the brake-horsepower at any given speed the friction-horsepower obtained at the same speed.

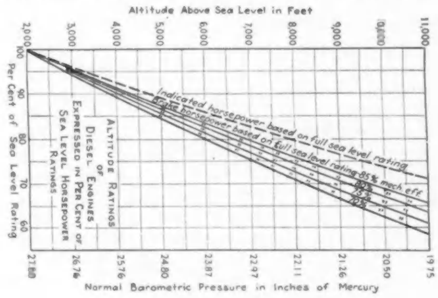
If the friction-horsepower and brake-horsepower tests are not made at exactly the same speeds, the friction-horsepower at any given speed can be obtained from the friction-horsepower curve plotted on the Curve Sheet. Tedious interpolation is thus avoided.

If it is desired to correct the results, a standard barometric pressure of 29.92 in. of mercury and a standard temperature of 520 deg. absolute, which is the same as 60 deg. fahr., shall be used in making the corrections.

Correction Formula[1]
$$B\text{-}Hp_c = B\text{-}Hp_o \times \frac{P_s}{P_o} \times \sqrt{\frac{T_o}{T_s}}$$

where $B\text{-}Hp_c$ = corrected brake-horsepower
$B\text{-}Hp_o$ = observed brake-horsepower
P_o = observed barometric pr. in inches of mercury
P_s = standard barometric pr. of 29.92 in. of mercury
T_o = observed absolute temp. in deg. fahr.
T_s = standard absolute temperature of 520 deg. fahr.

[2] The 1930 edition "Standards of Diesel Engine Manufacturers' Association," p. 14, gives the following approximate correction at constant temperature for i.hp. at various altitudes above sea level.



Rules and Directions for Use of Forms

Specification Sheet

(See corresponding numbers on Sheet B)

(3) The compression volume is the volume occupied by the charge when the piston is at the top of the compression stroke. To measure this volume, with the piston on dead center at end of compression stroke (*i.e.*, with both valves closed) fill the compression space from a graduate containing a known volume of light oil. Care must be taken to correct for leakage. Total volume of cylinder = piston displacement + compression volume. Give compression pressure at speed of maximum torque, or at speed of standard starter.

(4) State number of cylinders cast integral, whether offset, type of cylinder-head, whether water space is provided between adjacent cylinders and whether liners are used.

(6) State whether water or air-cooled. If the former, state whether pump or thermosyphon. Note if two pumps or thermostat are used. State type of pump. Give the diameter of the fan, the number and projected width of the fan blades and the ratio of the fan speed to the engine speed.

(7) Weight of piston with rings and pin should include weight of bushings, screws, or other piston-pin fastening-devices in the piston. Record all weights in pounds and decimal parts thereof. In measuring length of piston and distance from center of pin to top of piston, deduct any chamfer or crown at top of piston.

(8) Specify whether rings are concentric or eccentric; give name, sketch or description of special types. If oil-ring is used, state location.

(9) In giving weight of connecting-rod, include weight of all bushings, bolts, screws, and oiling devices normally attached to the rod. For piston-pin see (7). The connecting-rod must be horizontal while the ends are being weighed, the ends being supported by knife-edges or arbors. For V-type engines, state lower end construction.

(10) Under location, state whether in connecting-rod or piston.

(12) Diameters and lengths of bearings are to be stated in order from front to rear.

(14) Describe contour of cam, *i.e.*, uniform acceleration, tangential, etc.

(15 and 16) In case of non-poppet valves, describe and give dimensions.

(17) Reciprocating parts of directly operated poppet valves include valve, valve-lifter, valve-spring retainer and lock, and half of valve-spring.

(19) To determine valve-timing, mark top and bottom dead centers on flywheel rim; also points at which each valve opens and closes, engine cold and tappets set for standard clearance. Measure with flexible steel tape the length of arcs thus marked on flywheel. Reduce to degrees. Check both top and bottom dead centers for engines with offset cylinders.

(20) Moment of inertia of the flywheel is to be given in mass $\left(\frac{\text{weight in pounds}}{32.2}\right)$ and foot lbs. Moment of inertia is equal to the mass multiplied by the square of the radius of gyration. $I = MR^2$.

(21) The complete weight of engine should include oil, water, and all mechanically attached units necessary for normal functioning of engine, such as fuel-injection and air-injection systems, scavenging pump, generator, starting motor, fan and governor. Do not include such accessories as air compressor and air tank if they are used for starting only.

(22) State whether fuel is supplied to all the cylinders from a common line in which high pressure is maintained or whether each cylinder has its own fuel pump; whether the individual pump is mounted near the injection nozzle or as a separate unit.

(24) Give the pressure which is held in the oil system while the injection valve is closed.

(25) Describe the injection nozzle as completely as possible, stating whether air type or solid type, and giving details of construction and design.

(26) State location of nozzle in the cylinder, and distances relative to centers of inlet and exhaust valves and of piston head.

(27) Describe the injection valve completely.

(28) If air injection is used with the fuel supply, give the details of the air-injection pump as itemized.

(29) If a system of air scavenging is employed, describe it as outlined.

(30) Give the general type of lubrication system, *e.g.*, "recirculating splash"; "force-feed and spray"; "complete force-feed." Then describe in detail action of system and course taken by oil. State oil pressures and type of pump used.

(31) Describe method of starting the engine.

(32) Give list and description of accessories attached during the test.

Log Sheet and Curve Sheet

The Log Sheet and Curve Sheet have been designed for conveniently recording data and plotting curves covering the usual Standard Engine Tests. For special tests, these may be modified or special forms used.

If it is desired to correct data by the correction formula, the columns for Correction factor and Brake Load, Corrected should be filled in. Then *Pc* should be used to compute the data for the columns following.

S. A. E. DIESEL-ENGINE TESTING FORMS

SPECIFICATION SHEET—B

Name and Model ______ Serial No. ______ Date of Test ______

Manufacturer ______

*(1) General Type (Combustion and fuel injection system) ______ Cycle ______ Governor Used ______

(2) No. of Cyls. ______ Bore ______ in., Stroke ______ in., Piston Displ. per Cyl. ______ cu. in., Total ______ cu. in.

(3) Compression Vol. (V_c) ______ cu. in., Total Vol. of Cyl. (V) ______ cu. in., Compression Ratio $= \frac{\text{Comp. Vol.}}{\text{Total Vol.}} = \frac{V_c}{V} =$ ______

Compression Pressure ______ lb. gage at ______ r. p. m. with engine at normal full load operating temperature.

(4) Type of Cyl. Casting (single or enbloc) ______ Matl. ______ Liners ______

(5) Type of Valves ______ Location ______

(6) Cooling System ______

Fan Diam. ______ in., No. of Blades ______ Projected Width ______ in., Ratio of Fan to Engine Speed ______

(7) Piston, Type ______ Matl. ______

Wt. with Rings and Pin ______ lb., Length ______ in., Distance Center of Pin to Top of Piston ______ in.

(8) Piston-Rings (a) compression No. per Piston ______ Type ______ Width ______ in.

(b) No. per Piston ______ Type ______ Width ______ in.

(9) Connecting-Rod. Type ______ Length, c. to c. ______ in., Weight, Upper End ______ lb., Lower End ______ lb., Total ______ lb

(10) Piston-Pin Bearings, Diam. ______ in., Total Length ______ in., Matl. ______ Location ______

(11) Crank-Pin Bearings, Diam. ______ in., Length ______ in., Matl. ______ Type ______

(12) Crankshaft Bearings, No. ______ Diams. ______ Material ______ Lengths ______

(13) Camshaft Bearings, No. ______ Diams. ______ Material ______ Lengths ______

(14) Type of Cams ______ Type of Valve-Lifters ______

(15) Inlet Valves[1], No. per Cyl. ______ o.d. ______ in., Port Diam. ______ in., Lift ______ in., Seat Angle ______ deg.

(16) Exhaust Valves[1], No. per Cyl. ______ o.d. ______ in., Port Diam. ______ in., Lift ______ in., Seat Angle ______ deg.

(17) Weight of Valve Reciprocating Parts, Inlet ______ lb., Exhaust ______ lb.

(18) Valve-Spring Tension, Inlet Open ______ lb., Closed ______ lb., Exhaust Open ______ lb., Closed ______ lb.

(19) Valve-Timing, Inlet Valve Opens ______ deg. ______ Top Center, Closes ______ deg. after Lower Cente

Exhaust Valve Opens ______ deg. before Lower Center Closes ______ deg. ______ Top Cen te

(20) Flywheel, o.d. ______ in., Weight ______ lb., Moment of Inertia ______

(21) Weight of Engine ______ lb., Including ______

FUEL INJECTION SYSTEM

(22) Type of Fuel System ______

(23) Name and Model of Fuel Pump ______

Bore ______ in., Stroke ______ in., No. of plungers in Fuel Pump ______

(24) Normal Pressure in Fuel Supply System ______ lb. Injection pressure ______ lbs.

(25) Type of Injection Nozzle ______

Spray Orifices, Number ______, Size ______, Angle of Spray ______

(26) Location of Injection Nozzle ______

(27) Type of Injection Valve ______ How operated, Cam ______ Pump pressure ______

Fuel injection (engine at rest) begins ______ ends ______

Is injection-period timing fixed or variable? ______

AIR SYSTEM

(28) Type of Air Injection Pump ______ Displacement ______

No. of Stages ______, Pressure of Injection Air, ______ Pump Speed, ______ x Crankshaft Speed.

Diameters, 1st stage ______ in. 2nd stage ______ in. 3rd stage ______ in. Stroke ______ in. ______

(29) Pressure of Scavenging Air ______ Supercharger, type ______ pressure ______ lbs., temperature ______ deg.

Type of Scavenging Air Pump ______

Bore ______ in., Stroke ______ in., Number of Cylinders ______

Scavenging Air Pump, How Driven ______ Speed ______ x Crankshaft Speed.

LUBRICATION SYSTEM

(30) Type and Description (splash or force feed) ______

If cooled, describe method used ______

STARTING EQUIPMENT

(31) Electric ______ Inertia ______ Air ______ Auxiliary engine ______

Glow plug ______ Is incoming air preheated? ______ Method ______

ACCESSORIES

(32) Accessories, standard with the engine and used during test, Air filter, type ______ fuel filter, type ______

Lubricating, oil-filter, type ______ Water circulating pump, type ______

Generator ______ Starting air compressor ______

**See Notes Corresponding to Numbers Under "Rules and Directions" on Sheet A.*

[1] *If non-poppet type, describe and give dimensions from which areas can be computed.*

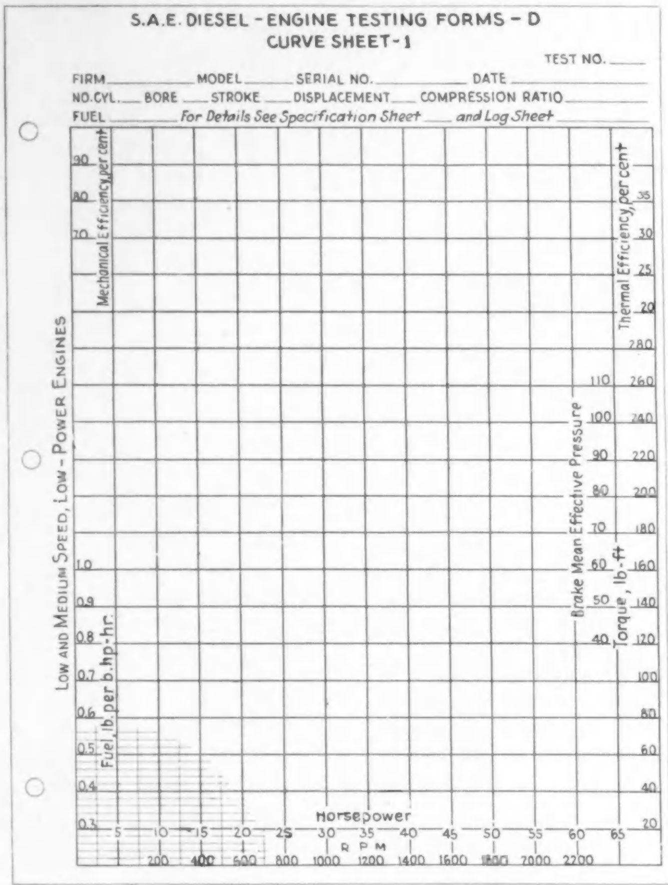
LOG SHEET—C No.........

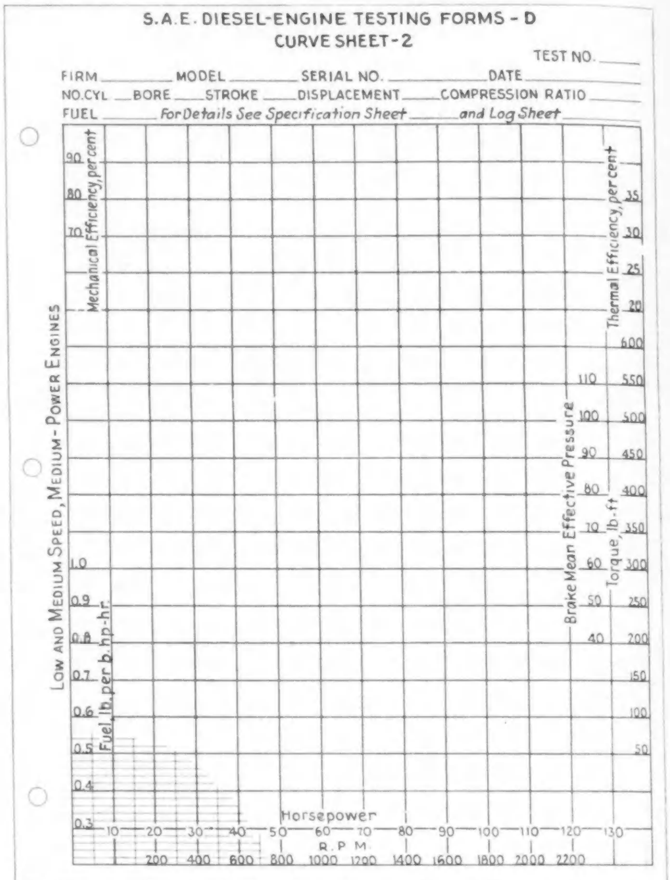
Name ______	Fuel ___ B.T.U. per Lb. ____ Sp. Grav. ___ at ___ deg. fahr.
Model ______ No. Cyls. ______	Dynamometer ______ Arm (R) ______ ft._
Bore ______ In. Stroke ______ In. Displ. (D) ______ Cu. In.	Humidity ______ per cent.
Laboratory ______ Date ______	Oil ______ Grade ______ Cold Test ______ deg. fahr.___
Observers ______	Saybolt Univ. Vis. at 130 deg. fahr.___ At 210 deg. fahr.___

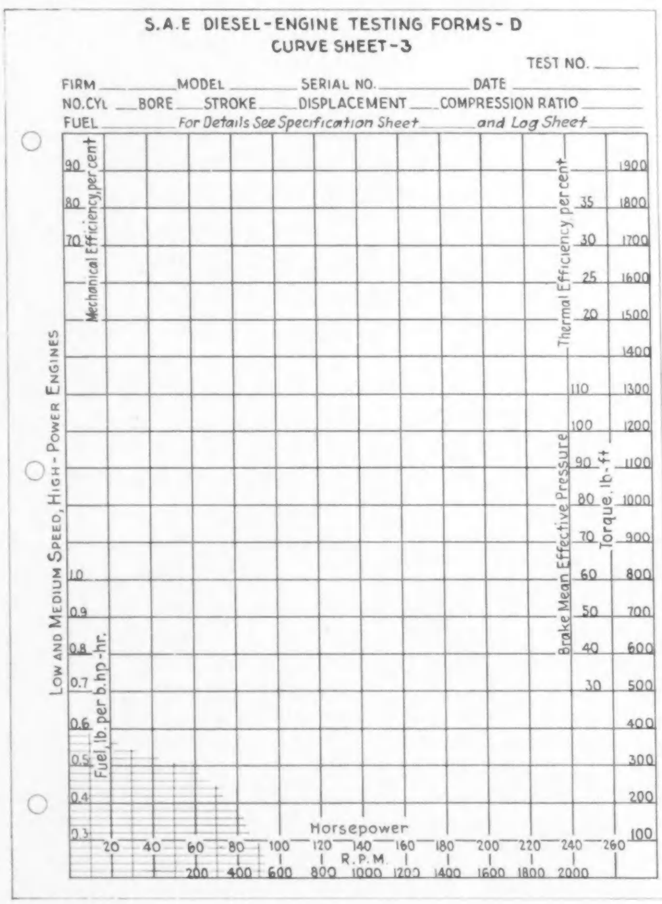
	Run Number	Symbol	Formula	1	2	3	4	5	6	7	8	9	10
BRAKE HORSEPOWER AND FUEL CONSUMPTION	Time Started		*										
	Duration of Run—Min.	t	*										
	Counter Start	C_o	*										
	Counter Finish	C_t	*										
	Total Rev.	r	$C_t - C_o$										
	Average R.P.M.	N	$\frac{r}{t}$										
	Barometer In. Mercury		*										
	Room Temp.		*										
	Correction Factor	C.F.	$\frac{P_s}{P_o} \times \sqrt{\frac{T_o}{T_s}}$										
	Brake Load at Arm R	P	*										
	Brake Load Corrected	P_o	CF×P										
	Torque Lb.-Ft.	T	PR										
	Brake M.E.P.	*np*	$\frac{150.8\ T}{D}$										
	Brake Hp.	B.Hp.	$\frac{PRN}{5252.1}$										
	Friction Hp. at N	F.Hp.	F.Hp. Curve										
	Indicated Hp.	I.Hp.	B.Hp.+F.Hp.										
	Mechanical Efficiency	M.E.	$\frac{B.Hp.}{I.Hp.}$										
	Temp. Jacket Water—In		*										
	Temp. Jacket Water—Out		*										
	Temp. Oil—In		*										
	Temp. Oil—Out		*										
	Oil Press., Lb.		*										
	Wt. Fuel Start	W_o	*										
	Wt. Fuel Finish	W_t	*										
	Lb. Fuel Used	W	$W_o - W_t$										
	Lb. Fuel Per B.Hp. Hr.	F	$\frac{60\ W}{t \times B.Hp.}$										
	Thermal Eff. Re B.Hp.	T.E.	$\frac{2545}{F \times B.T.U.}$										
FRICTION HP.	Time Started		*										
	Duration of Run—Min.	t	*										
	Counter Start	C_o	*										
	Counter Finish	C_t	*										
	Average R.P.M.	n	$\frac{C_t - C_o}{t}$										
	Brake Load at Arm R	p	*										
	Friction Hp.	F.Hp.	$\frac{pRn}{5252.1}$										
	Mean Temp. Jacket Water		*										

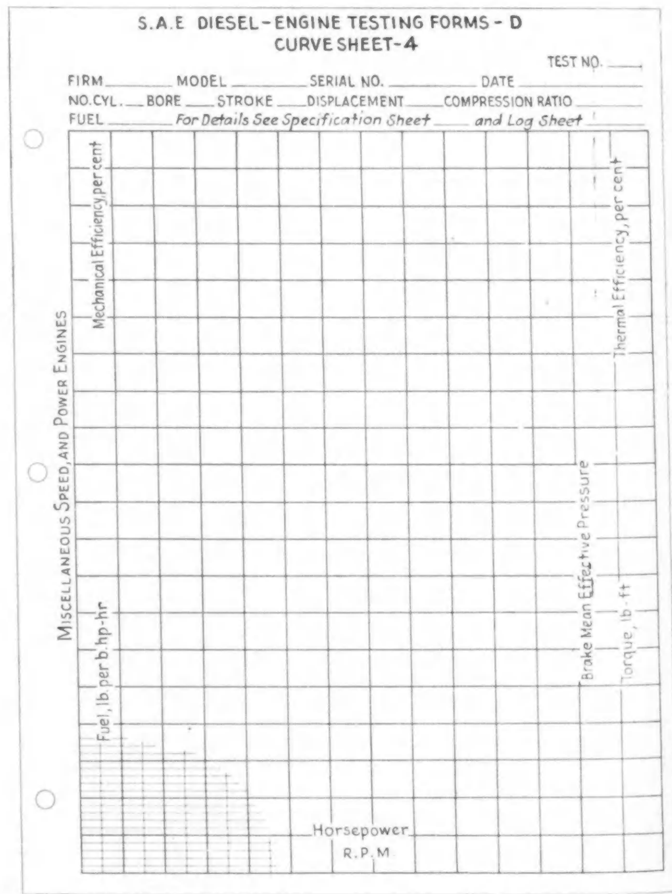
Above computed data corrected for barometer (Yes) and temperature (Yes)
*Laboratory readings (No) (No)

Refer to Specification Sheet No............
Refer to Curve Sheet No............









CURVE SHEETS FOR PROPOSED S.A.E. DIESEL-ENGINE TESTING FORMS

Proposed Aircraft Standards

Details of Specifications on Bolts and Nuts and Shock-Absorber Strut Ends

THE ACCOUNT of the action taken by the Aircraft Division at its meeting on Aug. 26, as given in the September issue of the S.A.E. JOURNAL, mentioned additional standards on aircraft bolts and nuts and shock-absorber strut ends, the details of which were omitted owing to the fact that THE JOURNAL for September went to press before this copy was received.

Bolts and Nuts

The accompanying tables indicate the additional standards for ¾, ⅞ and 1-in. aircraft bolts and nuts as approved for submission to the Standards Committee in January. These tables indicate only additions to the present specifications and do not show the entire specifications. The complete line of plain hexagon-head bolts that now constitute the S. A. E. Standard are to be revised if this recommendation is approved by the addition of dimension D^2 as indicated in the table.

Shock-Absorber Strut Ends

The illustration and the table on p. 490 of this issue of the S.A.E. JOURNAL give the dimensions of the proposed specifications on shock-absorber strut ends for use in aircraft as approved by the Aircraft Division at its meeting and submitted to all the members of the Division for letter-ballot.

PLAIN HEXAGONAL NUTS—AERONAUTIC

Proposed Additions to S. A. E. Standard

Nominal Size A[2]	Threads per Inch[3]	B Width Across Flats	N[1]	
			Full-Strength Nuts ±0.005	Thin and Check Nuts ±0.005
0.6250 (⅝)	..	...	..	..
0.7500 (¾)	16	1 1/16	9/16	⅜
0.8750 (⅞)	14	1¼	21/32	7/16
1.0000 (1)	14	1 7/16	¾	½

[1] For full-strength nuts $N=3A/4$. For check nuts and thin nuts for shear bolts ¼-in. diameter and larger $N=A/2$.
[2] Finished sizes include plating or protective coating.
[3] Threads are American Standard (NF), with Class 3 tolerances. NF indicates National Fine Pitch.

PLAIN HEXAGON-HEAD BOLTS—AERONAUTIC

(Proposed Revisions and Additions to S. A. E. Standard)

Nominal Bolt Size	Threads per In.[1]	A	B	C	D[2]	E	F	H	J	R	Tensile Strength, Minimum, Lb.
0.1640 (No. 8)					$0.1630 {+0.0000 \atop -0.0025}$						
0.1900 (No. 10)					$0.1890 {+0.0000 \atop -0.0025}$						
0.2500 (¼)					$0.2490 {+0.0000 \atop -0.0030}$						
0.3125 (5/16)					$0.3115 {+0.0000 \atop -0.0030}$						
0.3750 (⅜)					$0.3740 {+0.0000 \atop -0.0030}$						
0.4375 (7/16)					$0.4365 {+0.0000 \atop -0.0035}$						
0.5000 (½)					$0.4990 {+0.0000 \atop -0.0035}$						
0.5625 (9/16)					$0.5615 {+0.0000 \atop -0.0040}$						
0.6250 (⅝)					$0.6240 {+0.0000 \atop -0.0040}$						
0.7500 (¾)	16	1 1/16	1 1/16	13/32	$0.7490 {+0.0000 \atop -0.0045}$	13/16	15/16	0.141	3/64	¾	43,900
0.8750 (⅞)	14	1¼	1¼	15/32	$0.8740 {+0.0000 \atop -0.0050}$	29/32	1 1/16	0.141	3/64	⅞	60,000
1.0000 (1)	14	1 7/16	1 7/16	17/32	$0.9990 {+0.0000 \atop -0.0055}$	1	1⅛	0.141	3/64	1	80,800

[1] Threads are American Standard (NF), with Class 3 tolerances. NF indicates National Fine Pitch.
[2] Finished sizes include plating or protective coating.

NOTE—The marking may be an asterisk (*) inside the △, to differentiate from the old coarse-tolerance bolts now marked with △.

Extruded Aluminum-Alloy Shapes

ATTENTION is called to typographical errors in the tables on Extruded Aluminum-Alloy Channels and Extruded Aluminum-Alloy Bulb Channels, published in the S.A.E. JOURNAL for September, as follows:

On p. 361, in the table on Extruded Aluminum-Alloy Channels, the dimension of $S_{2\text{-}2}$ for the ⅞-in. size should be 0.03257 instead of 0.3257 as shown. Similarly, on the same page in the table on Extruded Aluminum-Alloy Bulb Channels, the dimension a for the 1-in. size should read 1/16 in. instead of 1 in., and dimension D for the 1½-in. size should be 9/32 instead of 9/16.

Nickel-Plating Information

(*Continued from p.* 483)

a small amount of some chloride such as nickel chloride or sodium chloride. For use in plating zinc-base metals it is common practice to have the bath also contain large quantities of sulphates other than nickel, such as sodium sulphate or magnesium sulphate.

Typical nickel-plating baths are similar to those shown in Table 1.

In addition to the materials shown above, many platers use additions of different materials such as acetic acid, citric acid, sodium citrate, hydrofluoric acid, nickel fluoride or Rochelle salts. The advisability of using such additions is open to question.

At the present time most nickel-

plating is done in baths that are at room temperature and at current densities of not over 20 amp. per sq. ft. There is a general idea that the acidity of the nickel-plating baths should be controlled with a value of about pH 5.7. Recent work has shown that the factors of temperature, current density and acidity may all be varied, and that these factors are just as important in nickel-plating as in chromium-plating.

For a bath with the composition *A*, as shown in Table 1, the effects of these variables of temperature, current density and acidity are shown in Fig. 1. Variations in nickel content, total sulphates, etc., will affect the exact location of the curves in Fig. 1, hence these curves should be used as a guide rather than as definitely fixed curves.

The principal troubles encountered in nickel-plating are roughness, peeling of the plate and pitting. Roughness appears to be caused by certain insoluble materials in the bath. Removal of these impurities by filtration usually corrects the trouble of roughness. "Bagging" the anodes is sometime used as a preventive measure.

Peeling is caused primarily by improper control of the factors shown in Fig. 1 and, to a less extent, by improper cleaning. It has been found that the troubles due to peeling are decreased if a hydrochloric-acid dip followed by a rinse in clear water comes between the regular cleaning operation and the actual nickel-plating.

Pitting is probably the most common trouble in nickel-plating at the present time. Many theories have been advanced to explain pitting, but in most cases the prevention of pitting involves either greater care in cleaning prior to plating or reduction of current density or the use of oxidizing agents in the nickel-plating bath.

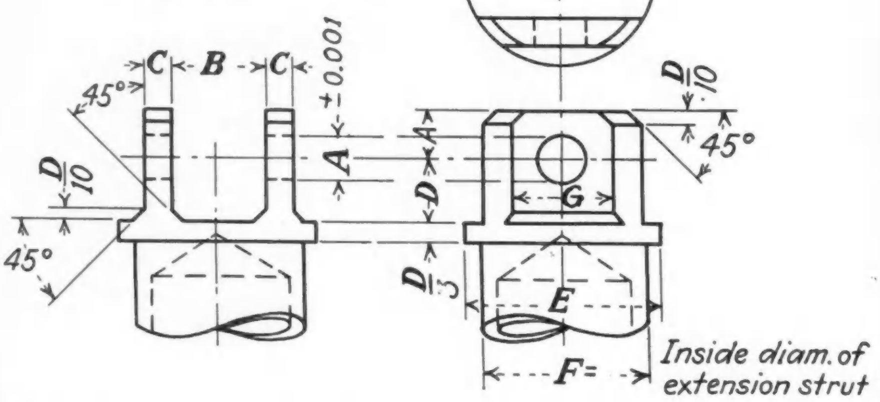
When resistance to corrosion is required, two plates composed of nickel and some other metal, such as copper, will usually give better results than a single plate of nickel of the same total thickness. For outdoor exposure on steel the total thickness of plate should be 0.001 in. or more, with the nickel at least one-half of the total plate. When chromium is to be applied over nickel the nickel should be plated under conditions that give good adhesion of the nickel-plate, and the nickel-plate should be thick enough to resist the tendency of the chromium-plate to cause peeling of the nickel.

In general, the bright polish on nickel-plates is obtained by buffing, but in some cases where the exposure conditions are so mild that the greater durability of a heavy buffed deposit is not required, a "bright" nickel-plate is obtained by proper control of the plating bath and plating conditions. These factors may involve the use of a small amount of cadmium or other addition agent in the bath, the use of low temperature and low current-density and the deposition of an extremely thin plate.

Many kinds of tanks have been used for nickel-plating, with wood, either pitch or lead lined, predominating. At the present time steel tanks with rubber linings are coming into use and seem to be giving satisfaction. For plating at elevated temperatures, the lead-lined or rubber-lined tanks are superior to the pitch-lined ones.

Many kinds of anodes have been used for nickel-plating and many troubles have been attributed to the use of im-

Shock-Absorber Strut Ends



STANDARD TUBE ENDS—SHOCK-ABSORBER STRUTS

Static Load per Strut		Ream *A*	*B*	*C*	*D*	*E* Min.
0	500	0.3125	0.630 0.625	0.260 0.250	9/16	1.25
500	1000	0.375	0.755 0.750	0.300 0.290	5/8	1.50
1000	1500	0.375	0.755 0.750	0.300 0.290	5/8	1.50
1500	2000	0.4375	0.880 0.875	0.330 0.320	11/16	1.75
2000	2500	0.500	1.010 1.000	0.370 0.360	3/4	1.93
2500	3000	0.5625	1.135 1.125	0.410 0.400	13/16	2.12
3000	4000	0.5625	1.135 1.125	0.410 0.400	13/16	2.12
4000	5000	0.625	1.260 1.250	0.440 0.430	7/8	2.43
5000	6000	0.750	1.510 1.500	0.500 0.490	1	2.93
6000	8000	0.750	1.510 1.500	0.500 0.490	1	2.93
8000	10000	0.875	1.760 1.750	0.550 0.540	1 1/8	3.25
10000	12000	0.875	1.760 1.750	0.550 0.540	1 1/8	3.25

A = Required diameter for bending and double shear on AN-Standard Bolt.
$B = 2A$ to allow for unilink of universal-joint.
$C = 1.5 \times$ Tie-rod-fork thickness.
$2C + B$ = Grip of AN-Standard Bolt.
$D = A + \frac{1}{4}$ in. for clearance, as radius of Lug $= A$.
E = Minimum diameter of flange when flat $G = 1.75 \times A$.

Note—This design is based upon the use of steel of minimum tensile strength of 125,000 lb. per sq. in.

proper anodes, but there is no general agreement upon any anode composition to meet the widely varying conditions in the industry.

The necessity of technical control of chromium-plating has called attention to the desirability of technical control in plating of all kinds, and it is probable that the more general application of technical control to nickel-plating will result in clearing up some of the troubles now experienced in nickel-plating.

CASTLE-HEXAGON NUTS—AERONAUTIC

Proposed Additions to S. A. E. Standard

Bolt Size *A*, Threads per Inch[4]	*B*[1]	*N*	*S* +0.010 −0.000	*O*[2]	*R*	*I*[3]
0.6250 (5/8)—18	...	..	..	..	..	..
0.7500 (3/4)—16	1 1/16	13/16	5/32	1/4	3/16	1/16
0.8750 (7/8)—14	1 1/4	29/32	5/32	1/4	3/16	1/16
1.0000 (1)—14	1 7/16	1	5/32	1/4	3/16	1/16

[1] Also size of hexagon.
[2] Also depth of slot.
[3] Distance from *A* to beginning of 3/32-in. radius, whose center is floating to satisfy curve.
[4] Finished sizes include plating or protective coating. All threads are American Standard (NF), with Class 3 Tolerances. NF indicates National Fine Pitch.

The Service-Manager's Job

K. T. Brown Outlines Characteristics a Successful Service Manager Must Possess

SOME of the qualifications and characteristics which a successful service manager must possess were stated by K. T. Brown, general manager of the Packard Motor Car Co., Boston, at a meeting of the New England Section. He said in part that he has met many men who were in charge of service departments but that they were far from being service managers in that, while they may have been good mechanics, organizers, salesmen or business men, they were not good service-managers because they did not possess a combination of these several abilities. He stated that the following qualities are essential:

(1) A keen desire to serve and a sympathetic interest in the public. This assumes a fair knowledge of psychology and salesmanship which creates the initiative and tact needed to reflect enthusiastic interest in the owner personally and in his personal service-problems.

(2) Organizing ability. This includes a knowledge of service routine, accounting and a business sense which is combined with the ability to produce "internal" as well as "external" good-will.

(3) Vision, including an open mind which seeks to acquire knowledge. This carries with it an ambition to progress and a desire to correct existing wrongs, together with analyses of present conditions and future possibilities rather than analyses of past complaints.

(4) Ability to radiate mechanical and business knowledge. Such ability must include the knowledge of how to pass on to others the data and information which the service manager has or can obtain. Learning new facts is not enough at present. A service manager does not progress according to the amount of his own knowledge, but rather by the passing of his knowledge on to others who must utilize it individually.

Good Service-Managers in Demand

After stating that good service-managers are increasingly in demand, Mr. Brown said that an ideal start for a service-manager's position is that of a mechanic who has come up through the ranks and who has been farsighted enough to acquaint himself with the business fundamentals that are so necessary in a managerial position. Another ideal start is that of a man who has had a college education which, if applied intelligently, has a market value. But anyone in the business can accumulate knoweldge which, if put to use, will command a higher market value. For example, the knowledge a good repairman has is an important factor already in his possession which is also applicable toward his becoming a successful service-manager, but it is only one factor and without the other factors needed such a man is only partially prepared.

A service-manager should know something about accounting, according to Mr. Brown. He should be able to read a profit-and-loss statement and know what it is all about, because the manager of any business should know whether the business is losing or making money and why. He must be familiar with the subject of overhead costs and what factors overhead includes. Further, he must be able to analyze and to control the direct expenses of his department.

The ability to obtain and *hold* customers is an art in itself, said Mr. Brown. Therefore, a study of salesmanship is highly desirable. So also is the problem of shop management, which is a science, and time spent in studying how to manage a shop economically will be well rewarded. A knowledge of equipment, scheduling systems, layouts and other important factors is needed to broaden the mental capacity of a service manager. Mr. Brown suggested that subordinates in service-station work give themselves a square deal by sacrificing some of their own time each day to study the subjects that will enable them to become fitted for the position of service manager.

Needed Details Outlined

As the service organization grows in volume, area of territory served and personnel, Mr. Brown continued, it becomes necessary that the business and all the details thereof be handled through very definite channels. In this manner the duties of each department are definitely determined and the responsibilities are suitably placed.

The trend of the business is indicated by written job-orders and, while they do not measure the business in dollars and cents of value, they do point out the number of customers who call for service and indicate which ones of the service salesmen are producing and which ones are not. Their evidence is not fully conclusive, because the characteristics of the particular service-men are not indicated but, as a whole, they indicate the amount of business fairly well. The written job-orders also measure the productivity of each department; that is, a certain number of productive men work for a certain number of productive hours and a certain number of nonproductive men are responsible for the details.

The report of productive hours made by the foreman gives a picture of how much time foremen have spent on productive work and of how much time they have spent on administration or nonproductive work. A productivity chart is used which represents the controlling factors in graphic form. From this, it can be determined at a glance when and where the high or the low production was reached and, by referring to the individual reports outlined in the foregoing, the reason for the high or the low production is easily determined. Another report enables a quick judgment to be made of whether or not the foremen are reaching the productive hours shown on their reports without carrying too many men in order to be able to take care of peak loads; in other words, this is a report of idle time.

Since shop supplies represent an expense that is directly controlled by the foreman of each productive department and for which he can be held directly responsible, a report of shop supplies is required. Knowing that the service manager has this report available for reference each month and that the only way that material can be drawn other than for a customer's job is by writing an order for shop supplies, the foreman is curbed if he has a tendency toward extravagance; but he knows he cannot be criticized if his orders for supplies are legitimate.

Other Factors Considered

In operating a service station of fairly large size, said Mr. Brown, it becomes necessary to establish specific hours and specific pay for those hours. In rendering service, it frequently becomes necessary that the men be required to remain after the hours specified. In that event, the hiring contract might possibly call for overtime pay. But if the men are held overtime and paid at the rate of time-and-one-half and such practice became chronic, it will decrease the service - station profits; therefore, it is good policy to

tabulate the time paid for when it is not productive. A record showing an analysis of painting jobs is kept and is available each month so that any job upon which money is lost is indicated, thus giving the service manager an opportunity to analyze particular cases and devise means of preventing similar future occurrences.

Service vehicles represent another direct expense that can easily become excessive if not watched carefully. The service-vehicle report requires the foreman to be in a position to explain to the satisfaction of the service manager any large expenditure during a given month, and also shows the earnings as well as the expense of the service vehicles.

According to Mr. Brown, in any well-organized automobile-selling agency, the separation from the sales department of the free work required on new cars, and the placing of the responsibility for free work on the service department is considered good policy. If this is not done, there is a loss of smooth operation because one department is issuing the orders and the other department is executing them. When the service department is made responsible for free work necessary on new vehicles, it is very important that an accurate record be kept of the amount expended each month; first, to rebut any argument by the sales department that the charges are excessive and, second, to determine just how much revenue is credited to the service department for this work. A table of cost-plus figures is very valuable for comparative purposes as well as for estimating costs to other departments within the organization for performing service work.

Unless an accurate record of accessories is kept monthly and yearly, Mr. Brown said that it cannot be determined definitely whether or not this particular department is accomplishing its work satisfactorily. A very good profit can be derived from the sale of accessories and the proper organizing of this phase of the business should be given due attention by the service manager.

One method of increasing the sale of accessories is by using the service salesmen and inspectors and paying them a commission. In this manner a two-fold benefit results; that is, increase in volume of this part of the business and an increase in earning power for the men involved. The sale of stock parts directly affects the earning of a service department. Unless the overhead and the ordering of material in this department are supervised very closely by means of regular reports, the stock department will not be profitable.

In conclusion, Mr. Brown said that complaints go hand-in-hand with a service department. A service manager always will strive for their elimination; but, although it probably is not possible, his standards for the elimination of complaints should be such as to result in striving to reach the 100-per cent mark. Even though the manager falls short of this, a good job will be accomplished at least. A close check on the origin of the complaints, whether or not they were justified and their disposition, is extremely important.

Vehicle-Driver Psychology

Kettering Broadcasts His Views on Fine Points All Drivers Must Be Trained To Practise

IN A recent radio address presented to the American people by the National Broadcasting Co., in cooperation with the National Safety Council, over a coast-to-coast network of 22 associated stations, Charles F. Kettering, general director of the General Motors Research Laboratories, Detroit, said in part that: "To get the maximum satisfaction from motor-vehicle operation it is very desirable first to check up the vehicles and then to check up the vehicle drivers. Last year we had something like 31,000 motor-vehicle fatalities, so-called. I have investigated many of these, and it is my impression that at least 95 per cent were driver accidents, because the failure was not in the vehicle itself."

The motor-vehicle manufacturer, his engineers and his production division are giving every attention in every line to the perfection of all kinds of motor-vehicle so far as safety is concerned, Mr. Kettering continued. It is always the first thing to be taken into consideration in any new design of automobile, motorcoach and motor-truck. What can we do to make this a safer vehicle? How can we make it so that it is easier for the driver to handle? are questions that they ask. All of these things are foremost, because we recognize that in the congested traffic with which we are now confronted the ease of handling the vehicle and its reliability are great and important factors so far as safety is concerned.

Safety in the Modern Motor-Vehicle

During the last few years the motor-vehicle industry has done many things to make the vehicle safer and better. The manufacturers have lowered the bodies, put on four-wheel brakes, improved the lighting, broadened the windshield, added balloon tires, improved the chassis and the steering apparatus in particular. All of these things have been added largely for reasons of safety. However, no matter how safe automobiles, motorcoaches and motor-trucks are made, they will not do anything more than what the driver dictates. He is in sole command as he drives along the highway. As he inspects his vehicle, its brakes, the engine, the carbureter adjustment, and the ignition system, he should analyze himself to determine whether he is in first-class condition also. Is he nervous? Does he get excited? Is he thinking of driving, or is he thinking of something else as he drives along the highway? With congested traffic it is important that he does not try to do too many things at once. It is about all one can do these days just to drive.

To my notion, said Mr. Kettering, there are two classes of drivers on the highway; those who are really going to some place in automobiles, motorcoaches and motor-trucks, and those who are just out riding. The drivers who are going to some place are, as a rule, the better drivers, not because they know more about driving, but because, in my judgment, the question of driving becomes one of prime importance in their minds for the time. We see on congested roadways two general streams of traffic, one moving at about 20 to 25 m.p.h. and the other 30 to 35 or 40 m.p.h. It is the passing of the slower traffic that is the cause of a great many accidents. If the drivers who must or who really desire to travel slow would watch, and when quite a number of vehicles get behind them they would take the opportunity to pull off to the side of the road and let these vehicles pass, it would add a great deal to the comfort and safety of everybody.

Rights on the Highway

Again there are two classes of drivers on the highway; those who feel that they have an absolute right on the highway, which certainly belongs to everyone, and those few who take the attitude that they are a sort of nuisance on the highway. I do not mean by this that they think other drivers are nuisances, but that they themselves are a sort of hazard; therefore, that they should watch out, not only that they do not have an accident themselves, but that they should try to keep other drivers from getting into trouble. I have said many times that in these days a driver has to drive three motor-vehicles, his own and two others. If he does not make up his mind to look out for the other drivers and to feel that he is somewhat of a hazard himself, he is very likely to assume the attitude that he has just as good a right to drive as he pleases as anybody else has, which is true, of course. But, if every driver assumes that point of view, it makes driving very much more difficult and very much more dangerous.

Intelligence versus Instinct

In addition to their being two kinds of drivers on the highway, each one of them is more or less a two-sided person. We are our "instinctive being," the one which reacts as things come along, without any thought whatever; then we are our so-called "intelligence person," that is, the person who looks and analyzes and tries to see what is the best thing to do under the circumstances. It is all right, if we are driving and have a chance to analyze; but, once in a while we do not have time to think, and then our instinctive reaction comes into being.

To illustrate what I mean, perhaps sometime in your life you have asked somebody to drop some medicine in your eye. It is very difficult to hold your eye open when you see the drop coming. The desire to shut the eye has nothing to do with intelligence; it is purely the instinctive reaction of the muscles of the body trying to shut the eye because of the protection which the eyelid affords. But if you think well enough and steadily enough, you can hold your eye open because you know that no bad result is going to occur. I mention this example because it amplifies exactly what happens in many cases in driving. When the unusual thing happens, our intelligence goes clear out of the picture and our reactions are entirely instinctive. It is for this reason that I never attempt to drive in Europe. I know that some Europeans drive on the opposite side of the road from the side we drive on in the United States, but I am afraid that if something happens when I am not thinking about that in particular I will drive to the wrong side of the road through sheer force of habit.

The Driver Who Straddles the Line

In looking over this question of motor-vehicle driving, we see a great many very common faults which could easily be avoided. In almost all States we have the roads divided with lines. If the traffic is not very congested we will find a great many drivers traveling astraddle of the line. This means that every time another driver approaches or tries to pass them he must swing over to his own side of the road. I believe that if drivers would make it a practice to drive on their own side of the road and learn to know exactly where the wheels of their motor-vehicles are when properly located on the road, they would be very much safer than to drive away from the danger and then, in cases of passing other vehicles, have to swing over rather suddenly. It takes only a little bit of practice until a driver learns to know exactly where the wheels of his vehicle are treading while he is driving. A good game for a driver to practice is to see how close he can set two stakes together and drive between them without knocking either stake down. A little spot pasted on the windshield affords a target whereby a driver can judge, as he sights down across it and the filler cap of the radiator, exactly where he is driving.

It has been my experience in many years of driving that if a driver will consider that the other fellow is likely to do something which he may not do, it is a great safety factor. I believe that drivers should always be upon the lookout and expect that somebody will come out of every blind alley and make the wrong turn; because, if drivers are assuming that, they are always on the alert and know just exactly how to stop and when to stop.

The Question of Safe Speed

To my notion, Mr. Kettering continued, the safe speed at which to drive is the one at which the driver has his vehicle under absolute control. If he cannot stop within the distance which he can see, he is taking chances. In night driving, it would depend entirely upon how far he can safely see and his ability to stop within that distance. The speedometer is not necessarily a measure of reckless driving. I have seen as much reckless driving at 15 or 20 m.p.h. as I have seen at 50 or 60 m.p.h. It is just a question of whether the person who is at the wheel is alert to what he is doing.

In addition to looking for side streets, railroad crossings and the like, I think that the question of knowing how to stop the vehicle in the shortest possible distance is important. Many drivers let their instinctive reactions put on the brakes to the fullest extent. This may not be the best way to stop; but, in their excitement they will not release the brakes and, naturally, the wheels skid, the vehicle swings across the highway and the condition is very much worse than if a much milder braking pressure had been used.

White Crosses and Railroad Crossings

Many crosses were placed to show where and how accidents had occurred in Ohio a few years ago, Mr. Kettering said. They divided themselves chiefly into four classes: Railroad crossings, road intersections, roadway turns and miscellaneous.

It was surprising to see the number of crosses there were at the railroad crossings. After all the warnings which the railroad companies had put up, drivers had insisted upon trying to beat the train to the crossing. This apparently was also true at the road intersections. With our present traffic-lights, this particular danger has been largely avoided. At the roadway turns, unquestionably the accidents were due to fast driving or lack of attention on the part of the drivers.

My own plea, said Mr. Kettering, is that each driver make it an invariable rule to drive intelligently at all times, to take into consideration his fellow drivers, to keep his mind clear, his eyes and ears open, to be alert, to be attentive and, above all, to remember that he is driving an instrument of potential tragedy while still enjoying one of the greatest blessings of our civilization.

Man Wanted!! Reward Offered!!

Why Is He Wanted? This man is wanted because until he is found a vacancy will exist in the ranks of a well-known and well-established manufacturing company. The officers responsible for the progress of that company need him to fill the vacancy, and they are therefore making diligent efforts to find him.

The man sought is an engineer possessing certain outstanding characteristics. He prepared for his profession by acquiring a suitable education, —actively acquiring it, not simply submitting to one, or merely exposing himself to a course of instruction somewhere. His experience has been of sufficient length, variety and importance to justify a company in offering him a position of unusual attractiveness, for the record of his past gives them confidence that his future will be one of steadily increasing responsibility and authority well earned.

His personality is one of his greatest assets and it will constitute a distinct advantage to the company that finds and employs him. It will enable him to fit easily into the place now awaiting him in the organization, to function there harmoniously and to advance in due course to a place of greater importance on the staff. It will cause him to secure the respect and loyalty of his subordinates and the cooperation of his fellow-workers. It will, moreover, win for him the approbation of his official superiors, who will realize that a personality deservedly liked within an organization will quite probably merit and receive the same esteem in contacts with customers and others outside the organization.

REWARD OFFERED!!!
READ ABOUT IT!!!

What Is the Reward and Who Will Get It? The reward is a large one and, oddly, it is indefinite in amount. More than oddly, rewards will accrue both to the man sought and to the people seeking him.

The man will benefit because, when his prospective employers find him and learn that he possesses the desired qualifications, they will offer him an attractive initial salary with prospects of even greater remuneration as his usefulness to the company increases. Besides the pecuniary reward, he will receive the not-to-be-measured compensation that comes from stretching one's capabilities to achieve success in a new undertaking, experiencing as a result a strengthening and growing of one's capabilities and a further reaching out to fill the requirements of a yet larger job.

The company officials who find him will receive their reward in the realization that they have secured for their organization a man of sound education, broad experience and outstanding personality, who will give to the interests of their work his ability, his energy, his loyalty, his enthusiasm and his vision. He will thus contribute to the improving of their product and the increasing of their profits.

Many Men will wish to have a part in the reward and many will indeed have a share of it. Those fortunate ones participating in the large reward will be regarded by the unthinking as merely lucky, whereas their so-called luck will really be a matter of their realizing that, when such a reward is at stake,

IT
PAYS
TO
INVESTIGATE!

How Can This Man Be Found? How can he be brought into communication with a company requiring an engineer with just the qualifications that he possesses?

The Society's Employment Service is maintained for the very purpose of bringing together companies that are seeking worthwhile men to fill attractive positions and the men who are qualified to hold such positions.

All factors are so carefully considered that, as a result, round pegs do not attempt to fit into square holes nor do round holes try to receive square pegs.

If You Are an Employer, tell us your needs and we will be glad to do everything possible to supply you with the right type of man for each vacancy that you wish filled. There is NO FEE for this service.

If You Are a Member of the Society, unemployed or seeking a better position than your present one, let us know your qualifications, and we will do all that we can to place you satisfactorily. This service is rendered WITHOUT CHARGE to all S. A. E. members in good standing who wish to avail themselves of it.

One feature of the Employment Service is the sending of semi-weekly bulletins, showing positions available and men available. Let us know if you desire to be put on the mailing list to receive either the bulletins of POSITIONS AVAILABLE or the bulletins of MEN AVAILABLE.

Questions concerning the Employment Service may be addressed to the office of the Society, 29 West 39th Street, New York City, or to the S. A. E. Detroit Section office, 2-136 General Motors Building, Detroit.

Applicants Qualified

The following applicants have qualified for admission to the Society between July 10 and Sept. 10, 1930. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

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OLSON, RUDOLPH J. (J) brakeman, Studebaker Sales Co., *Chicago;* (mail) 944 North Lavergne Avenue.

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OSBORN, BALDWIN (J) service engineer, Wright Aeronautical Corp., *Paterson, N. J.;* (mail) Room 19, Y. M. C. A.

OSMAN, RALPH T. (M) dumptor department manager, National Equipment Corp., *Milwaukee;* (mail) 2413 Stratford Court.

PATTERSON, NOBLE RAY (J) assistant laboratory engineer, International Harvester Co., *Fort Wayne, Ind.;* (mail) 3325 Alexander Street.

PAUL, DAVID SPIERS (F M) manager, technical sales department, Anglo-American Oil Co., Ltd., 36 Queen Anne's Gate, *London, S. W. 1, England.*

PETRUL, PAUL (A) 297 Pleasant Avenue, *New York City.*

PRICE, E. T. (M) chief engineer, Acme Motor Truck Corp., Haynes Street, *Cadillac, Mich.*

PROCTOR, ARTHUR (A) inspection foreman, Surface Transportation Corp., *New York City;* (mail) 2050 Webster Avenue.

REARDON, MARION D. (M) branch automobile superintendent, Standard Oil Co. of New Jersey, *Richmond, Va.*

REDDIG, JAMES C. (J) engineering staff, Grover Loening Co., 305 East 36th Street, *New York City.*

RICHARDS, ARTHUR JAMES (J) 1724 Holcomb Avenue, *Detroit.*

ROENIGK, J. A. (M) head, automotive division, Cleveland Trade School, *Cleveland;* (mail) 4373 West 50th Street.

ROLAN, GEORGE TRAVIS (J) service, Cadillac Motor Car Co. of Canada, Ltd., *Oshawa, Ont., Canada.*

RUSSEL, COLIN (M) manager, Russel Brothers, Ltd., *Fort Frances, Ont., Canada.*

SKINNER, SHERROD E. (M) chief engineer, Ternstedt Mfg. Co., *Detroit;* (mail) 899 Longfellow.

SPENGLER, WALTER J. (M) chief engineer, Scintilla Magneto Co., Inc., *Sidney, N. Y.;* (mail) P. O. Box 929.

SQUIER, G. K. (M) manager, lubricating department, Pan American Petroleum & Transport Co., 122 East 42nd Street, *New York City.*

STADLER, ALBERT J. (A) shop foreman, E. A. Wildermuth, 1102 Atlantic Avenue, *Brooklyn, N. Y.*

STANCLIFFE, WILLIAM L. (A) vice-president, in charge of sales, American Car & Foundry Motors Co., 30 Church Street, *New York City.*

STAROST, JOHN C. (M) shop engineer, Marmon Motor Car Co., *Indianapolis;* (mail) 1438 Rembrandt Street.

STEWART, GEORGE W. (A) retail passenger-car sales manager, Frank D. Saupp, Inc., 5928 Penn Avenue, *Pittsburgh.*

STUBBS, HAROLD WILLIAM (M) 13930 Woodward Avenue, *Detroit.*

SULLIVAN, HAROLD W. (M) chief chemist, Independent Oil & Gas Co., Drawer G, *Okmulgee, Okla.*

Applicants for Membership

The applications for membership received between Aug. 15 and Sept. 15, 1930, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANDERSON, R. A., chief inspector, Ingersoll Steel & Disc Co., *Galesburg, Ill.*

AVERY, IRVING F., chief engineer, Jacob Press Sons, *Chicago.*

AXTATER, KARL S., captain, United States Army, Wright Field, *Dayton, Ohio.*

BAKER, BRYANT E., assistant sales manager, Standard Oil Co. of New York, *New York City.*

BARD, O. L., secretary, Michigan Tool Co., *Detroit.*

BEALE, HORACE A., 3rd, testing engineer, International Motor Co., Mack Plant, *Allentown, Pa.*

BRADY, GEORGE F., foreman, service and experimental, Kinner Airplane & Motor Corp., *Glendale, Calif.*

CAGE, W. M., territory representative, Apollo Magneto Corp., *Kingston, N. Y.*

CARROLL, ELLSWORTH W., chief mechanical engineer, Kalif Corp., *Emeryville, Calif.*

CHAMP, KENNETH B., president and general manager, Lincoln Oil & Paint Co., *Cleveland.*

COBLE, J. B., Station C., Box 63, *Cincinnati.*

COCKLIN, HENRY S., chief engineer, Dornier Co. of America, *New York City.*

COCHRANE, ALPHEUS B., president, Maryland Truck Equipment Corp., *Baltimore.*

DAVIS, A. F., junior engineer General Motors Research Corp., *Detroit.*

DEPUE, ROBERT N., treasurer, Essex Sales Co., *Newark, N. J.*

DONOHUE, ROBERT M., president, manager, Danker & Donohue, *Boston.*

ENGEL, WILLIAM F., mechanical engineer, Hercules Motors Corp., *Canton, Ohio.*

FAIRBANK, MILES H., assistant to president and general manager, American Propeller Co., *Baltimore.*

FARR, GRAY, Kermath Mfg. Co., *Detroit.*

FARRAR, EARL V., designer, Wright Aeronautical Corp., *Paterson, N. J.*

FIELDS, CHRIS J., body minor-layout draftsman, Pierce-Arrow Motor Car Co., *Buffalo.*

GARDNER, ARTHUR B., president and treasurer, United Oil Co., Inc., *Baltimore.*

GUSTAFSON, CARL H., draftsman, International Motor Co., *Allentown, Pa.*

HONJUKU, T., Lieutenant, Imperial Japanese Navy, Japanese Naval Inspector's Office, *New York City.*

KERR, HENRY HAMPTON, JR., Bendix Brake Co., *South Bend, Ind.*

KLINE, WILSON W., commercial supervisor, Frigidaire Sales Corp., *Los Angeles.*

LEONARD, LLOYD HUGO, aeronautical engineer, research department, Edward G. Budd Mfg. Co., *Philadelphia.*

MAYO, WILLIAM N., sales manager, The Farfall Co., *Detroit.*

MCMANUS, LESLIE S., parts and service representative, General Motors Products of Canada, *Edmonton, Alberta, Canada.*

O'CONNOR, WILLIAM, city mechanician, Corporation of the City of Hamilton, *Hamilton, Ont., Canada.*

OLSON, ALBERT, manager, Dill Mfg. Co. of Canada, Ltd., *Toronto, Ont., Canada.*

POINTER, NORMAN ALEXANDER, production engineer, General Motors (Australia) Proprietary, Ltd., *Melbourne, Australia.*

RHODES, WALTER P., head of motor mechanics department, Technical High School, *Calgary, Alberta, Canada.*

ROESCH, J. ALBERT, JR., president, Steel Sales Corp., *Chicago.*

ROSS, D. A., layout engineer, Willys-Overland, Ltd., *Toronto, Ont., Canada.*

SCHALL, HAROLD L., mathematician, Studebaker Corp., *South Bend, Ind.*

SEAGREN, JOHN, designing engineer, Fairbanks Morse & Co., *Beloit, Wis.*

SHOEMAKER, C. E., JR., chief inspector, Command-Aire, Inc., *Little Rock, Ark.*

SPICE, BURTON G., purchaser of gasoline and oil, Greyhound Management Co., *Cleveland.*

STEWART, HAROLD R., secretary, Metropolitan Omnibus & Transport Co., Ltd., *New South Wales, Sydney, Australia.*

TALIAFERRO, LINDSAY CAVE, service station department, lubrication sales promotion, Standard Oil Co. of New Jersey, *Baltimore.*

UNITED REFINING CO., *Warren, Pa.*

WARNER, CHARLES H., vice-president, Warner Electric Brake Co., *San Marino, Calif.*

WILLIAMSON, RALPH J., general superintendent, Trimont Mfg. Co., *Roxbury, Mass.*

WILLINK, ARTHUR, first lieutenant, Ordnance Department, United States Army, Frankford Arsenal, *Philadelphia.*

WOODWARD, representative, The Texas Co., *Baltimore.*

Notes and Reviews

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

AIRCRAFT

Proof of the Theorem Regarding the Distribution of Lift Over the Span, for Minimum Induced Drag. By W. F. Durand. Report 349. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930, 7 pp. and 4 appendixes. [A-1]

The proof of the theorem that the elliptical distribution of lift over the span is that which will give rise to the minimum induced drag has been given in a variety of ways, generally speaking too difficult to be readily followed by the graduate of the average good technical school of the present day. An effort is made in the form of proof in this Report to bring the subject more readily within the grasp of this class of readers. The steps in proof, briefly outlined, are as follows:

(1) Given a basic distribution of lift across the span denoted by *a*, with a second supplementary distribution denoted by 1. Then it is shown that the induced drag of lift *a* in the downwash due to lift 1, and the induced drag of lift 1 in the downwash due to lift *a*, are equal, and that the total effect of the small distribution 1 on the induced drag will be measured by twice either of these small quantities.

(2) Next, two small changes are assumed in a basic distribution *a*. These are represented by 1 and 2, and are further assumed to be equal in amount and opposite in algebraic sign, thus leaving the original lift unchanged in amount but changed in distribution. Under these conditions it is then shown that, for the distribution *a* to be that for minimum induced drag, the change in induced drag due to this small change in distribution must be zero.

(3) It is shown that, for any pair of small changes such as 1 and 2, the only value of the basic downwash which will meet the condition of step (2) is downwash that is constant across the span.

(4) It is known mathematically that the elliptical distribution across the span is that which gives a constant value of the downwash and hence, as a result of (1), (2), (3), this must be the distribution which gives the minimum value of the induced drag.

Water-Pressure Distribution on a Flying-Boat Hull. By F. L. Thompson. Report No. 346. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930; 18 pp. [A-1]

This is the third in a series of investigations of the water pressures on seaplane floats and hulls, and completes the present program. It consists of determining the water pressures and accelerations on a Curtiss H-16 flying boat during landing and taxiing maneuvers in smooth and rough water.

The results show that the greatest water pressures occur near the keel at the main step, where the maximum pressure is approximately 15 lb. per sq. in. From this point maximum pressures decrease in magnitude toward the bow and chine. Pressures of approximately 11 lb. per sq. in. were measured at the keel slightly forward of the middle of the forebody when taking off in rough water. The area of the forebody subjected to considerable pressure is roughly a triangle having its base at the step and its apex on the keel at the load-water line forward. On the bottom between steps, a maximum pressure of 8 lb. per sq. in. is nearly uniform.

A vertical acceleration of 4.7 gravity is the greatest value encountered in landings and is considerably greater than any other value recorded. It was found that 3 gravity is approximately the maximum to be expected in take-offs in rough water, and that this value was exceeded during only a few landings. A longitudinal acceleration of 0.9 gravity was once attained in a landing in rough water, and 0.7 gravity is not unusual for take-offs in rough water. The maximum lateral acceleration attained in crosswind landings is approximately 0.5 gravity.

The results show that the landing loads were usually borne by an area near the main step, and that rough water may cause large loads to be applied near the middle of the forebody.

Aircraft Accidents, Method of Analysis. Report No. 357, Committee on Aircraft Accidents. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930, 17 pp. [A-1]

This report presents the experience of the Committee and the Departments of War, Navy and Commerce in the study of aircraft accidents for the purpose of analyzing them in such a way as to assist in reducing their frequency and severity. Careful consideration was given to the psychological and physiological problems involved in the piloting of aircraft, for it is believed that these factors have an important bearing upon the number and kinds of accidents that occur.

Strength of Welded Joints in Tubular Members for Aircraft. By H. L. Whittemore and W. C. Brueggeman. Report No. 348. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930; 41 pp. [A-1]

This investigation was undertaken to make available to the aircraft industry authoritative information on the strength, weight and cost of welded joints of a number of types. Chromium-molybdenum tubing was oxyacetylene welded under procedure control.

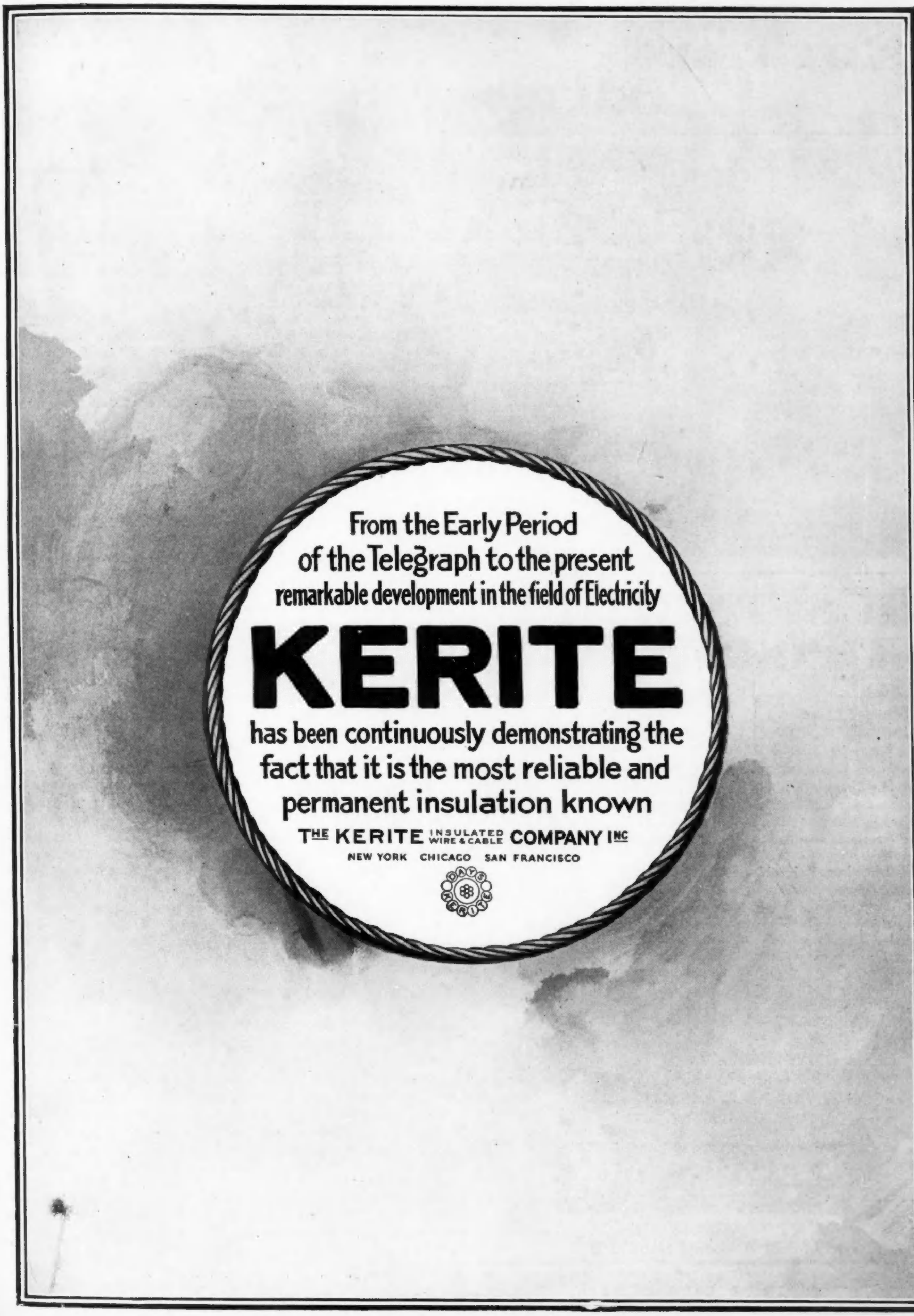
Following a program prepared from information supplied by manufacturers, 40 joints were welded under procedure specifications and tested to determine their strength. It was found that the point of minimum strength and hardness of the base metal is sharply defined and is located about ½ in. from the weld center. If a T joint is loaded to high bending stresses near the joint, it is more satisfactory to gain strength by increasing the size of the tube rather than by adding plates, straps or the like. Reinforcement by means of U straps increases the efficiency to 87 per cent.

A joint can be made almost as efficient by welding large gussets between the intersecting tubes, but the weight and the time required to fabricate are excessive. The best reinforcement for the lattice joint is one that reinforces it against collapse of the tube. Cracking is an important problem when gusset plates are used for reinforcement. A procedure for welding each type of joint should be worked out experimentally, and designs which cannot be welded consistently without cracking should be discarded.

The Story of Aircraft Tubing. By S. L. Gabel and H. C. Knerr. Published in *Aviation*, March 28, 1930; pp. 632. [A-1]

This is the first of a series of three articles that present an excellent picture of the history, manufacture and characteristics of tubing and interesting details concerning improvements in the machinery used in its manufacture. With the great savings in weight made possible by use of properly heat-treated

(*Continued on p.* 30)


From the Early Period
of the Telegraph to the present
remarkable development in the field of Electricity
KERITE
has been continuously demonstrating the
fact that it is the most reliable and
permanent insulation known
THE KERITE INSULATED WIRE & CABLE COMPANY INC
NEW YORK CHICAGO SAN FRANCISCO

Personal Notes of the Members

Means for Studying Combustion Wave

Details of a new method and apparatus for studying the combustion wave in an engine were disclosed by Dr. Lloyd Withrow, W. C. Lovell and **T. A. Boyd**, of the General Motors Corp. Research Laboratories, at the meeting of the American Chemical Society in Cincinnati during the second week of September. By means of apparatus developed as the result of cooperative efforts, it is now possible for the first time to determine precisely what occurs at different stages of the combustion stroke of an engine. The authors explained that the mechanism, which operates with the rapidity of a machine-gun, accumulates samples of the burning gas at frequent stages of the stroke. These samples are then analyzed by chemistry to trace the progress of the combustion wave.

As a result of the application of this method, two modifications of the previous general conception of combustion in the cylinder were said to be necessary. The combustion wave was found to proceed at a definite rate, instead of a flash of flame throughout the combustion space following the instant of ignition; and the rate of flame propagation in a detonating charge is not affected by the detonating conditions, even when tetraethyl lead is present in the fuel, until after three-quarters of the charge has burned.

Robert D. Abbott was recently appointed manager of Goodrich Silvertown, Inc., of Long Beach, Calif. He previously held the position of manager of the tire-development department of the Miller Rubber Co., of Akron, Ohio.

William F. Aug recently became identified with the Texas Co. at its Bayonne, N. J., plant, where he is engaged as a mechanical engineer in antiknock research. His previous position was as airplane designer with the Keystone Loening Aeronautical Co., of New York City.

Roscoe V. Bates, a former cooperative engineering student with the Chevrolet Motor Co., in the General Motors Institute at Flint, Mich., is now in charge of local sales for the Industrial Machinery Co., at Warren, Ark.

Karl Beaver has secured the position of laboratory assistant with the Ethyl Gasoline Corp. engineering laboratory at Detroit. He was previously a student at Yale University.

Albert E. Berdon, former consulting engineer of East Orange, N. J., is now serving as research engineer for the Antioch Industrial Research Institute, Inc., at Antioch College, Yellow Springs, Ohio.

John A. Binder, formerly in charge of the experimental laboratory of Durant Motors, Inc., of Detroit, is now employed as an experimental engineer with the Continental Motors Corp., also of Detroit.

Karl W. Bock, who has been serving the Mack International Motor Truck Corp. as division bus manager of the Western district, at Omaha, Neb., has been transferred and is now branch manager of the Milwaukee branch of that company.

Capt. E. C. Bomar, of the Ordnance Department, U. S. A., has been transferred from Headquarters, 5th Corps Area, Fort Hayes, Columbus, Ohio, to the Army Industrial College, Munitions Building, City of Washington.

Robert J. Broege is now vice-president and general manager of the International Engineering Corp., of Chicago. He was previously connected with the Buda Co., of Harvey, Ill., of which he was chief engineer of the Diesel-engine division.

Capt. M. V. Brunson, of the Quartermaster Corps, U. S. A., who has commanded the Atlantic Motor Transport Pool, the 38th Motor Transport Company, and the 19th Motor Repair Section at Fort Davis, Canal Zone, since December, 1927, has been ordered by the War Department to report at Fort McPherson, Atlanta, Ga., on Dec. 12, for assignment as Quartermaster of that post. Captain Brunson will leave Panama on Sept. 10 and, while on a three months'

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Personal Notes of the Members

Continued

leave of absence, will take a two months' special course at the Coyne Electrical School, South Paulina Street, Chicago. He is a member of the 1930 Transportation and Maintenance Activity Committee.

Howard C. Carter, who has been a student at Cornell University, recently obtained a position as conversion operator with the Atmospheric Nitrogen Corp., of Hopewell, Va.

Arthur E. Corbin was recently appointed New York zone manager for the Oakland Motor Car Co., of Pontiac, Mich. His previous position was as assistant to the manager of the commercial-car division of the Chevrolet Motor Co., of Detroit.

The Keasbey & Mattison Co., of Ambler, Pa., announces the appointment of **Charles S. Dahlquist** as automotive sales engineer, with headquarters at Detroit. Mr. Dahlquist formerly held the position of sales manager of the Superior Universal Products Co., at Bowling Green, Ohio.

George W. DeBell was recently appointed as the head of stress analysis, weight control and static test departments of the Fairchild Airplane Mfg. Co., of Farmingdale, N. Y. His previous connection was as engineer of the Aviation Corp., of Buffalo.

Austin W. Deyo, former general manager of the Deyo Oil Co., Inc., of Binghamton, N. Y., recently became identified with the Colonial Beacon Oil Co., Inc., in the capacity of operating manager of its New York State division.

Wade Doty has been promoted from the post of sales engineer of the Two Way Shock Absorber Co., of Jamestown, N. Y., and is now chief engineer for that company.

John A. Edgar, a former student of the University of California, is now serving the Fokker Aircraft Corp. of America, at Glendale, W. Va., as aeronautic engineer.

O. G. Evans has relinquished the position of sales engineer for the Bearing Service Co., of Australia, Proprietary, Ltd., of Melbourne, and accepted a position with the SKF Ball Bearing Co., Ltd., also of Melbourne, Australia.

Charles William Fairbank, who has been serving the Standard Oil Co. of New Jersey as branch automobile superintendent, at Charleston, W. Va., is now an engineer in the motor-vehicle department of that company at Newark, N. J.

Volney C. Finch recently assumed his new duties as professor of aeronautical engineering at the Alabama Polytechnic Institute in Auburn, Ala. Mr. Finch is a former United States Navy lieutenant.

Russell W. Fowler has become identified with the extension division of the University of Wisconsin, at Madison, as an assistant professor of drawing. He previously was an instructor in the department of practical mechanics at Purdue University, West Lafayette, Ind.

Gilbert R. Fuller, having recently finished his studies at Carnegie Institute of Technology, is now employed as a student engineer on Diesel-engine assembly by the Chicago Pneumatic Tool Co., at Franklin, Pa.

Mendel Glickman, a former mechanical engineer for the International Harvester Co., at Milwaukee, is now employed by the Russian Government at Tractorstroy, Stalingrad, U. S. S. R., as production manager for tractors.

Rudolph R. Grant, having relinquished his post as president and chief engineer of the Dayton Airplane Engine Co., of Dayton, Ohio, has entered the independent field in Dayton as a consulting engineer.

Announcement has been made that **Robert S. Grimshaw** has resigned from the Griswold Motor Body Co., of Detroit, where he was in charge of sales and design, and has recently joined the sales engineering staff of the Murray Corp., of America, also of Detroit.

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Personal Notes of the Members
Continued

M. Hamon, who has been serving the Shell Eastern Petroleum Corp., of New York City, as an automotive engineer, has been advanced to the position of assistant manager in the aviation department of the offices of that company.

Dr. D. Roberts Harper, 3d, has resigned as consulting thermal engineer for the General Electric Co. and associate professor of physics at Union College, Schenectady, N. Y., to become a member of the staff of the coal research laboratory at the Carnegie Institute of Technology in Pittsburgh.

Hubert C. Harper was recently appointed as zone parts and service manager of the Montreal zone of General Motors Products of Canada, Ltd. His previous position was that of supervisor of General Motors of Canada, Ltd., at Oshawa, Ontario.

Warren S. Harris, until recently a student at the University of Illinois, is now employed as a research and development engineer by the Prest-O-Lite Co., of Indianapolis.

D. C. Heitshu is now associated with the engineering department of the J. I. Case Co., of Racine, Wis. He previously held the position of assistant agricultural engineer, in charge of farm power and machinery research, at the Virginia Agricultural Experiment Station at Blacksburg, Va.

Ju Hsun Hou has given up his post as engineer in the automotive division of the Chinese Mfg. Co., of Tientsin, China, and is now occupying the position of assistant engineer in the technical department at the Mukden Arsenal, at Mukden, China.

Hugh A. Johnson, former assistant engineer with the Hupp Motor Car Corp., of Detroit, has accepted a position at the Olds Motor Works, at Lansing, Mich.

Neil T. Kelley is now serving as a production engineer with the Govro-Nelson Co. of Detroit. Before accepting this position, Mr. Kelley was a student at the University of Michigan.

Anson M. Keller has relinquished his post as engineer with the Ryan Aircraft Corp., of Robertson, Mo., and become a chemical engineer for the Bemis Bros. Bag Co., of St. Louis.

Lloyd F. Kernkamp, a former University of Minnesota student, is now an engineer with the Tennessee Copper Co., of Copperhill, Tenn.

Maurice L. Kerr was recently appointed chief engineer of the Brockway Motor Truck Corp., of Cortland, N. Y. He was formerly chief engineer of the Indiana Truck Corp., of Marion, Ind.

Paul H. Kimberlin, a former Massachusetts Institute of Technology student, is now a student in the engineering department of the Carnegie Steel Co., at Youngstown, Ohio.

M. J. Kittler, having given up his post in the experimental laboratory of the International Harvester Co., of Chicago, is now pursuing his new duties in the engineering laboratory of the Stromberg Carburetor Co., of South Bend, Ind.

H. C. Kramer, who has been serving the Stutz Motor Car Co., of Indianapolis, as master mechanic and superintendent of assembly, has become superintendent for the Martin-Parry Corp., also of Indianapolis.

LeRoy F. LeGros, a former checker in the engineering department of the Hupp Motor Car Corp., of Detroit, is now serving as assistant designer with the Muncie Products Division of the General Motors Corp., at Muncie, Ind.

Marvin E. Lickert, a former layout man of the DeVilbiss Mfg. Co., of Toledo, Ohio, is now engaged in design work for the Surface Combustion Co., also of Toledo.

Hans W. Lindemann recently became identified with the Nationale Automobil Gesellschaft, of Berlin, Germany,

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Personal Notes of the Members

Continued

in the capacity of designing engineer. He previously served the Illinois Steel Co., of Gary, Ind., in the same capacity.

Frank C. Mason, a former student at the Carnegie Institute of Technology, is now working as a student engineer for the General Electric Co., at Fort Wayne, Ind.

Charles H. Metz is now serving the Metz Products Corp. and the Holbrook Mfg. Co., of Los Angeles, as vice-president in charge of engineering. He previously held the position of mechanical engineer with the Metz Products Corp., of the same city.

Erwin H. Meyer, a former technician and assistant to Dr. L. Michaelis, of the Rockefeller Institute for Medical Research, of New York City, is now a student at the Massachusetts Institute of Technology, in Cambridge, Mass.

Chester S. Moody, having resigned as superintendent of the Killefer Mfg. Corp., of Los Angeles, is now serving the Northwest Engineering Co., of Green Bay, Wis., as metallurgical engineer.

A farewell banquet was given recently to **Curtis L. Moody**, who, for the last 14 years, was superintendent of the Fisk Rubber Co.'s eastern plant at Chicopee Falls, Mass., by his business associates in that company. Mr. Moody resigned his post with the Fisk company to take up duties as factory manager of the Dominion Rubber System, a subsidiary of the United States Rubber Co., at Kitchener, Ontario, Canada.

R. F. La Mothe has assumed the duties of chief engineer for the John C. Hoof Co., of Chicago. His previous connection was with the American Metal Products Co., of Milwaukee, which he served as sales manager.

George Muench, who has been serving the Georgia Power Co., of Atlanta, in the capacity of automotive engineer, recently became superintendent of transportation for the Georgia-Florida Motor Lines, Inc., of Jacksonville, Fla.

Announcement has been made that **Alfred S. Otton**, formerly manager of the trade sales department of the Moto-Meter Gauge & Equipment Corp., of Long Island City, N. Y., is the new salesmanager of the Hurley-Townsend Corp., of New York City.

C. E. Packer, copywriter for automobile accounts, has relinquished his post with Williams & Cunnyngham, of Chicago, to become associated with the Robert June industrial advertising organization, of Detroit.

Walter S. Peper is now a sales engineer with the Bellanca Aircraft Corp., of New York City. He was, until accepting his present position, manager of the accessory sales division of the Curtiss Flying Service, Inc., also of New York City.

Lemuel Porter, who had been serving the Curtiss Aeroplane & Motor Corp., of Garden City, N. Y., as foreman of drafting, recently severed this connection to become fittings designer for the Sikorsky Aviation Corp., of Bridgeport, Conn.

W. G. Retzlaff is now employed as an engineer with the General Motors Truck Co., at Pontiac, Mich. Prior to accepting this position, he was transportation engineer with the Fruehauf Trailer Co., of Detroit.

George E. Reynolds, who recently resigned as manager of the Chicago branch of the Coleman Motors Corp., of Chicago, is now Washington sales representative of the Heil Co., of Milwaukee, with headquarters in the City of Washington.

C. B. Ripley is now serving the Pan American Grace Airways, at Cristobal, Canal Zone. He is a former New York University student.

James B. Robinson has become a member of the engineering department of the International Harvester Co., at Fort Wayne, Ind. He was previously a student at Cornell University.

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Personal Notes of the Members

Concluded

John B. Scott is now chief inspector of the Muncie Products Division of the General Motors Corp., of Muncie, Ind. His former connection was as superintendent of the Viking motor plant at the Olds Motor Works, at Lansing, Mich.

Carl Schulze, a former Massachusetts Institute of Technology student, is now employed as a mechanical engineer in the development department of the Eastman Kodak Co., of Rochester, N. Y.

James M. Shoemaker has accepted the post of lecturer in mechanical engineering at the University of Southern California, at Los Angeles. He was previously a research engineer with the Engineers Aircraft Corp., of Stamford, Conn.

John Douglas Starkweather, a former Yale University student, is now a cadet engineer with the Detroit Edison Co., of Detroit.

W. R. Strickland resigned his post as assistant chief engineer of the Cadillac Motor Car Co., of Detroit, in the early summer after a connection of seven years with that company, and spent a vacation in Estes Park, Colorado. His present plans contemplate a more complete change and rest for the winter, with a sojourn in Florida or California during the bad-weather months in the North. He does not intend to think of professional work until he has regained his health, but is keeping in touch with the march of events in the automotive and industrial fields.

K. A. L. Suez was recently appointed a sales engineer and field service representative for General Motors, Inc., of China, with headquarters at Shanghai. He is a former student of the University of Michigan.

Having resigned as manager of the eastern highway division of the Universal Crane Co., of Elyria, Ohio, **G. Herbert Taylor** has assumed the duties of manager of the eastern territory for the Bay City Foundry & Machine Co., of Bay City, Mich., with offices in New York City.

Joseph R. Thompson has left the production division of the Fokker Aircraft Corp. of America, at Hasbrouck Heights, N. J., and is now serving as supervisor of the central repair shop, in the automotive division of the Shell Eastern Petroleum Products Co., of New York City.

Edward Trapani is now an airplane stress analyst, serving the National Aircraft Engineers, Inc., of the City of Washington. He is a former student of the University of Michigan.

J. R. Van Dyke has accepted the position of instructor at the School of Mechanic Arts, North Dakota Agricultural College, Fargo, N. D. His previous position was that of associate professor of mechanical engineering in the gas-engine division of the University of Minnesota, at Minneapolis.

James F. Vickers, a former layout draftsman with the Fokker Aircraft Corp., of Hasbrouck Heights, N. J., is now employed as layout draftsman and designer by the Aircraft Improvement Corp., of New York City.

G. E. Voglesong, having left Durant Motors, Inc., of Detroit, for which he was a district sales representative, is now sales engineer and district manager for the Bragg-Kliesrath Corp., of Long Island City, N. Y.

J. Russell Walsh, former production engineer for the General Motors Export Co., of New York City, recently joined the staff of the *Automotive Daily News*, of New York City, as engineering editor.

Announcement has been made that **Vedder White**, former assistant district manager of the Auto Sales & Service Co., of Philadelphia, is now in charge of the New York City branch of the Brockway Motor Truck Corp.

Oscar W. Wortman, former vice-president of the Aircraft Steel Co., of Wichita, Kan., was recently made president and treasurer of that company.

Notes and Reviews

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alloy-steel tubing, little doubt exists of its present and future use in aircraft construction.

Span Load Distribution on Two Monoplane Wing Models as Affected by Twist and Sweepback. By Montgomery Knight and Richard W. Noyes. Published in July, 1930. Technical Note No. 346; 7 pp., 9 figures. [A-1]

The Pressure Distribution Over a Douglas Wing Tip on a Biplane in Flight. By Richard V. Rhode and Eugene E. Lundquist. Published in August, 1930. Technical Note No. 347; 19 pp., 9 figures. [A-1]

Investigation of the Variations in the Velocity of the Air-Flow About a Wing Profile. By Walter Repenthin. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt.* Published July 15, 1929. Technical Memorandum No. 575; 18 pp., 6 figures. [A-1]

The Vortex Theory and Its Significance in Aviation. Part I. Vortex Theory, Part II. Wing Theory. By A. Betz. Translated from *Unterrichtsblätter für Mathematik und Naturwissenschaften,* Vol. 34, 1928, No. 12. Technical Memorandum No. 576; 27 pp., 22 figures. [A-1]

Determination of the Best Cross-Section for a Box Beam Subject to Bending Stresses. By A. Von Baranoff. Translated from the 1927 Yearbook of the Deutsche Versuchsanstalt für Luftfahrt. Technical Memorandum No. 577; 9 pp., 5 figures. [A-1]

Calculation of Tapered Monoplane Wings. By E. Amstutz. Translated from *Schweizerische Bauzeitung,* April 5, 1930. Technical Memorandum No. 578; 20 pp., 16 figures. [A-1]

Theory of the Landing Impact of Seaplanes. By Wilhelm Pabst. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt* May 14, 1930. Technical Memorandum No. 580; 36 pp., 14 figures. [A-1]

Structural Details of German Light Airplanes. By Martin Schrenk. Translated from *Zeitschrift des Vereines Deutscher Ingenieure,* March 15, 1930. Technical Memorandum No. 579; 25 pp., 44 figures. [A-1]

The foregoing Technical Notes and Memoranda were published during July and August by the National Advisory Committee for Aeronautics, City of Washington.

Acoustical Properties of Some Sound Collectors for the Aircraft Sound-Locator. By Jûichi Obata and Yahei Yosida. Report No. 62. Published by the Aeronautical Research Institute, Tokyo Imperial University, Japan, July, 1930; 15 pp., illustrated. [A-1]

Several types of sound collectors for the aircraft sound-locator are in existence. The authors of this report acknowledge that the aural and electrical procedures have merits but assert that room still exists for improvements.

The report covers experiments carried out with two parabolic reflectors and two exponential horns, the objects being to obtain exact knowledge concerning the acoustic properties of some typical sound collectors and to determine their field of application.

It was found that the parabolic reflector has an excellent directive property, though its magnifying power is not large. For practical use a much larger reflector, together with a powerful amplifier, should be employed.

The single horn was found to be almost non-directive for sounds of the lower frequencies, so that, whether the aural or electrical reception method is used, the time or phase difference at two horns should be utilized in order to employ the horn for the aircraft sound-locator.

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Notes and Reviews

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Airplane Chassis Design—The Shock-Absorbing Unit. By Alfred S. Niles. Published in *Airway Age*, July, 1930, p. 918. [A-1]

This and two succeeding articles in the August and September issues of *Airway Age* contain a scholarly discussion of landing-gear problems, the use of tires as shock-absorbers, and some features of shock-absorber design.

The Air Annual of the British Empire. Founded and edited by Squadron Leader C. G. Burge, O.B.E., A.R.Ae.S.I. Published by Gale & Polden, Ltd., London; Vol. II, 1930, 800 pp. and index. Price, 21 shillings. [A-3]

This volume resembles its predecessor in appearance, completeness, number of advertisements, high quality of its articles and arrangement of material. It contains a mine of information pertaining to aeronautics and the British trade. The material is arranged in 19 subdivisions, under the following headings: Empire Aviation, Service Aviation, Airships, Civil Aviation, Sporting Flying, Air Survey, The British Aircraft Industry, Aero-engines, Aero-engine Accessories, Airscrews, Aircraft, Steels and Alloys, Wheels and Brakes, Wireless, Navigation and Instruments, Air Survey and Photographic Equipment, Flying Equipment, Airdrome and Airport Lighting and Equipment, British Commercial Aircraft, and Aircraft Production of the Dominions. The articles are contributed by leading aeronautic authorities, both official and civilian.

In addition to the valuable list of abbreviations in common use in British service and civil aeronautics, there is a compilation under the heading General References of data that are especially enlightening to those interested in international aviation. The book also contains an astonishing number of photogravure plates, monochromes, three-colored plates, suntone plates and maps.

Statistics contained in the reference section show the progress made in all branches of British aviation last year. Significant figures on air-route miles, club membership, private ownership, licenses of different types and certificates of registration prove that aviation is gaining ground in public opinion.

Simplified Aerodynamics. By Alexander Klemin, professor of aeronautical engineering, Daniel Guggenheim School of Aeronautics, New York University. Published by the Goodheart-Wilcox Co., Inc., Chicago, 1930; 323 pp. [A-3]

This is a textbook for beginners. The explanations are amply illustrated by problems and charts.

King's Cup Air Race, 1930. Published in *Flight*, July 4, 1930, p. 728. [A-3]

The King's Cup Air Race started at 7 a.m. on July 5 with 101 entries, 88 of which started and 61 finished the 750-mile course before 8 p.m. the same evening. The entries included 22 different types of aircraft, which proclaims the activity of the last year in light-airplane production. Almost all competitors were evenly matched, and no machine had a handicap at less than 80 m.p.h.

July 5 was a perfect summer day. Making allowances for the ideal weather, with little if any wind, the race gave evidence of increased reliability of modern airplane engines and competent pilots.

Added impetus to the race was the entry of planes by the Prince of Wales and his brother, Prince George.

In addition to the King's cup, several money and cup prizes were offered by private individuals, newspapers and oil companies for other races that were run during the day.

A woman pilot, Miss Winifred Brown, flying a Cirrus 111 Avian, came out best in the handicap, having flown a perfect course and gained on her rivals from the start. Thus once more the British sporting world has had a jolt,

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another national competition having been captured by a member of the fair sex. Alan S. Butler, in a Moth with a Gipsy 111 engine, finished 15 min. later.

Accounting for Aviation Operators. By Lawson L. Putman and Franklin D. Meyers. Published in *Airway Age*, March, 1930, p. 348. [A-4]

Commercial aviation has developed into a paying business. This necessitates an accurate knowledge of costs, which is obtained through accounting. From the data secured, useful information will be derived that will be helpful in reducing expenses and in setting prices, rates and tariffs.

Books, forms and equipment for use in accounting by aviation schools and airports are described in detail in this series of articles, which began in the March issue of *Airway Age*. In fact, this important phase of aviation, which is rarely brought to the attention of the public, is ably handled.

Der Gefährliche Flache Trudelflug und Seine Beeinflussung. By Richard Fuchs and Wilhelm Schmidt. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, July 14, p. 325, and July 28, 1930, p. 359. [A-4]

The aims of the present article are: to set forth in complete detail the conditions that make a flat spin possible; to show the magnitude of forces that bring about a disturbance in the equilibrium of forces and moments characteristic of a flat spin; to weigh the means proposed for bringing an airplane from spinning to normal flight and to make design recommendations for the avoidance and overcoming of spinning.

Tests were made on a low-wing Junkers monoplane. The conclusion reached is that an increase in the horizontal tail surfaces during a spin is a quick and certain way to bring the airplane to normal flight, and a construction is illustrated whereby this can be achieved. The spinning tendency of an airplane, the author states, can be eliminated by correct design of the vertical tail surfaces and rear of the fuselage, and he makes certain recommendations in this connection.

CHASSIS PARTS

Le Joint de Hooke. By N. Causan. Published in the *Journal de la Société des Ingénieurs de l'Automobile*, May, 1930. p. 1024. [C-1]

Interest in the front-wheel drive has again brought to the forefront of consideration the Hooke joint, which is here subjected to a theoretical and practical examination.

Three types of universal-joint are described and the corresponding Hooke joints utilizing these constructions. The principles of operation of the latter are set forth, together with the methods of calculating the forces to which they are subjected. Application of these calculations to front-wheel-drive problems is made, a diagram shows the disposition of the forces for eight different conditions encountered in normal operation, certain design recommendations are made, and an illustrative example is worked out.

In conclusion, the author notes favorably the fact that front-wheel-drive cars can have a larger steering angle than conventional vehicles, the maneuverability thus obtained being particularly advantageous in city driving. Overloading of the transmission which results when the maximum torque and steering angle are used simultaneously can be remedied by careful design and a slight reinforcement of the transmission. For the present it seems advisable to limit steering angles to 45 deg., but the common usage of angles as large as 60 deg. is foreseen for the future.

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Problème du Silence des Engrenages. By M. Broulhiet. Published in *Journal de la Société des Ingénieurs de l'Automobile*, May, 1930, p. 1010. [C-1]

In seeking a generalized and scientific basis for attacking the subject of gear noises and their prevention, the author resorts to the mathematical treatment of vibrations developed by Helmholz between 1860 and 1870. Automotive sounds and noises, he points out, are only the audible manifestations of vibrations set up in parts which act either as oscillators or resonators. The periodic forces setting up these vibrations have their origin in the lack of balance in rotating parts, in the periodic explosive cycle of the engine, or in variation in the transmission of power caused by badly cut gear teeth.

After examining the subject of vibrations in general, the author considers the criteria for judging what vibrations produce disagreeable sounds. In the third section he applies the theory developed to practical questions of gear design and material, emphasizing particularly his conviction that the automotive industry has much to learn with regard to the types of steel that should be placed in contact. Gear material, he asserts, influences not only wear, and hence vibration, but also gear efficiency.

A Simple Transmission Dynamometer. By E. Giffen and C. M. White. Published in *Engineering*, May 16. 1930, p. 621. [C-3]

The instrument described is considerably shorter than the torsion-meter type. Its novelty does not lie in the principle of torque action but in its application. There are no delicate parts that are liable to give rise to mechanical trouble. This eliminates the need for any special care in handling, which makes the instrument suitable for workshop use.

The dynamometer has been used for many months in the engineering laboratory of King's College, London, and has proved reliable and very satisfactory.

Des Couples Côniques et leur Montage dans les Ponts Arrière. By Raymond Stern. Published in the *Journal de la Société des Ingénieurs de l'Automobile*, April, 1930, p. 978. [C-4]

In this article on differential design and construction, the author, who is engineer of the Citroen company, discusses for the most part the methods followed by his organization. Some general principles of differential-gear design are set forth, and the composition, physical characteristics and heat-treatment of the materials used are given. In treating the subject of production, much attention is devoted to the Gleason gear-cutting machines, and the schedule of operations of the Citroen company are detailed.

A testing instrument of which special mention is made is the megascope, which measures and registers differential vibration. This device is stated to differ from the microphone in that it is influenced only by the vibrations of the particular part or assemblage which it is testing. Education of the personnel, which is said to contribute largely to the success of American factories, is stated to be also one of the Citroen policies.

ENGINES

Electric Generators for Aircraft. By Dale S. Cole. Published in *Aviation Engineering*, July, 1930, p. 16. [E-1]

Because of extensive study of the application of electrical generators to its airplanes by the Air Corps of the United States Army, its experience and requirements have been influencing factors in design and performance.

Early attempts to use existing types of automotive generators soon led to recognition of the limitations and turned attention to the voltage-regulated type of generator, in which the voltage is controlled within close limits by means of an external control element that is responsive to changes of voltage.

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The advantage of this voltage-regulated generator has brought about the almost universal adoption of this type as standard aircraft equipment.

The generator shaft is protected from sudden shock and stress by a flexible-coupling member consisting of a special laminated-spring structure.

The present generating equipment for aircraft may be practical for today, but with the tendency to use more and more electrical energy on modern planes, the manufacturer must realize, asserts the author, that the source of electrical energy becomes more important and continuous effort must be made to improve it.

Wind-Driven Generators. By J. H. E. Thomsen. Published in *Aviation Engineering*, July, 1930. p. 27. **[E-1]**

The limited information available on the characteristics of wind resistance and the power output of wind-driven generators was the impetus for the test reported upon in this article. The results obtained agree with a theoretical consideration of the aerodynamics and mechanics of the blade mechanisms, which led to the conclusion that the head resistance of the blade must decreases with an increase in forward speed.

The Oil Engine in Aeronautics. By E. E. Wilson. Paper presented at the Third National Oil and Gas Power Meeting of The American Society of Mechanical Engineers, at State College, Pa., June 12 to 14, 1930. **[E-1]**

Perhaps the most striking advance made in aircraft engines has been the reduction in weight of the cooling apparatus. Cooling methods may be classified as (*a*) the indirect process and (*b*) the direct process. Systems using cooling media flowing through a radiator come under the term "indirect process," whereas those in which the waste heat which passes through the cylinder-walls is transmitted directly to the air are classified under "direct process." The latter makes possible the complete elimination of such cumbersome things as radiators, their piping, pumps and heat exchangers.

The aircraft engine has advanced steadily, the author points out, by developing more horsepower with a given piston displacement and reducing the weight of the structure necessary to such displacement. The first advance has been attained largely by higher crankshaft speeds, and the second by refinement in design. These refinements have resulted from the employment of a single-row radial form and the elimination of the cooling system.

Two ways in which to use heavy oil are (*a*) through injection into the cylinder and the employment of the Diesel cycle or some modification thereof, and (*b*) injection into the cylinder, using the straightforward Otto cycle now used in gasoline engines. Of the two, the straight Diesel process has certain advantages, as follows: elimination of the electric-ignition system, with corresponding reduction in weight and the elimination of ignition interference with radio, and the superior economy of the Diesel cycle.

If the Diesel engine can eliminate the costly ignition system and carburetion, it should be superior, thinks the author, to the gasoline engine.

Some Phases of Light-Weight Diesel-Engine Design. By P. B. Jackson. Paper presented at the Third National Oil and Gas Power Meeting of the American Society of Mechanical Engineers at State College, Pa., June 12 to 14, 1930. **[E-1]**

From an economic point of view, the light-weight Diesel engine is justified because it has been shown, according to the author, to give a lower cost per horsepower, lower cost of operation, reduction of engine size and reduction in time of work accomplished.

Various methods employed to attain the desired results, especially to produce an engine much under conventional weight, are set forth.

Increase in the mean-effective-pressure ratings at the sacrifice of specific fuel consumption may or may not be

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justified. The present low specific fuel consumption places the Diesel engine in an enviable position as a prime mover. Any increase in the m. e. p. would increase in direct proportion the amount of heat to be dissipated, and this is likely to cause mechanical failures if means are not provided for its dissipation.

The principal reason for the use of aluminum alloys in the construction of cylinder-heads, exhaust valves, pistons, connecting-rods, valve gears and the like is that the peculiar properties of these alloys are preeminently suited to the application for which they are recommended.

From 70 to 80 per cent of the total weight of a Diesel engine is available for aluminumization. Its only drawback is that it increases the cost of the engine, but the low engine-weight should have a definite economic appeal.

Lubrication of Aircraft Engines. By William Lee. Published in *Aircraft Engineering*, August, 1930, p. 212. [E-1]

Mr. Lee discusses the contribution made by Messrs. Thornycroft and Barton in their recent experiments upon oils and their conclusions therefrom, reviewed in this department of the S.A.E. JOURNAL for July, 1930, and takes exception to some of their remarks. He believes that they should undertake a series of tests in which the quantity of oxygen allowed to reach the fog at the underside of the piston can be varied, because their contention that the origin of sludge is above the piston rather than below cannot be sincerely held.

Experiments with castor oil and mineral oils show that the former is excellent when run for a limited period under severe conditions but is deficient when run for an extended period. At a high temperature it goes through stages of increasing viscosity until it reaches a solid gum-like mass. Mineral oil obviates some of these defects but produces a large amount of sludge.

The author feels that Messrs. Thornycroft and Brown are not fair in their judgment of Bright Stock because the results of practice show that the best work has been done in oil containing it.

Water-Cooled Aero Engines. By A. J. Rowledge. Published in *The Journal of the Royal Aeronautical Society*, July, 1930, p. 578. [E-1]

Competition has resulted in better performance of both water-cooled and air-cooled engines. Reliability is regarded as the most important quality of an engine, but we must distinguish between reliability and length of life or length of time it can be run between overhauls, writes the author. This brings up the question of cost. In this respect, operation of the water-cooled engine has the advantage for both fuel and oil consumption but the air-cooled engine is the more economical to overhaul.

While the line of development points toward relative reduction in cylinder capacity on a given crank with high mean effective pressure and rate of crankshaft revolutions, the answer to the reduction in resistance, asserts the author, is the general adoption of evaporative or steam cooling, which has automatic cylinder-temperature regulation and a lighter cooling system containing less water, and the possibility of a cooling system without drag.

The most important development in recent years is the application of the geared centrifugal blower to supercharge the engine cylinders, either to restore ground power at height or to ground-boost. The general type of blower has a compact arrangement of the unit with the carbureter and the drive from the crankshaft.

Real progress has been made in fuel economy. The best results have been achieved by raising the compression as far as possible, with the aid of special fuel to minimize detonation. Valuable work has been done in the investigation of the antiknock values of fuels and in standardizing results.

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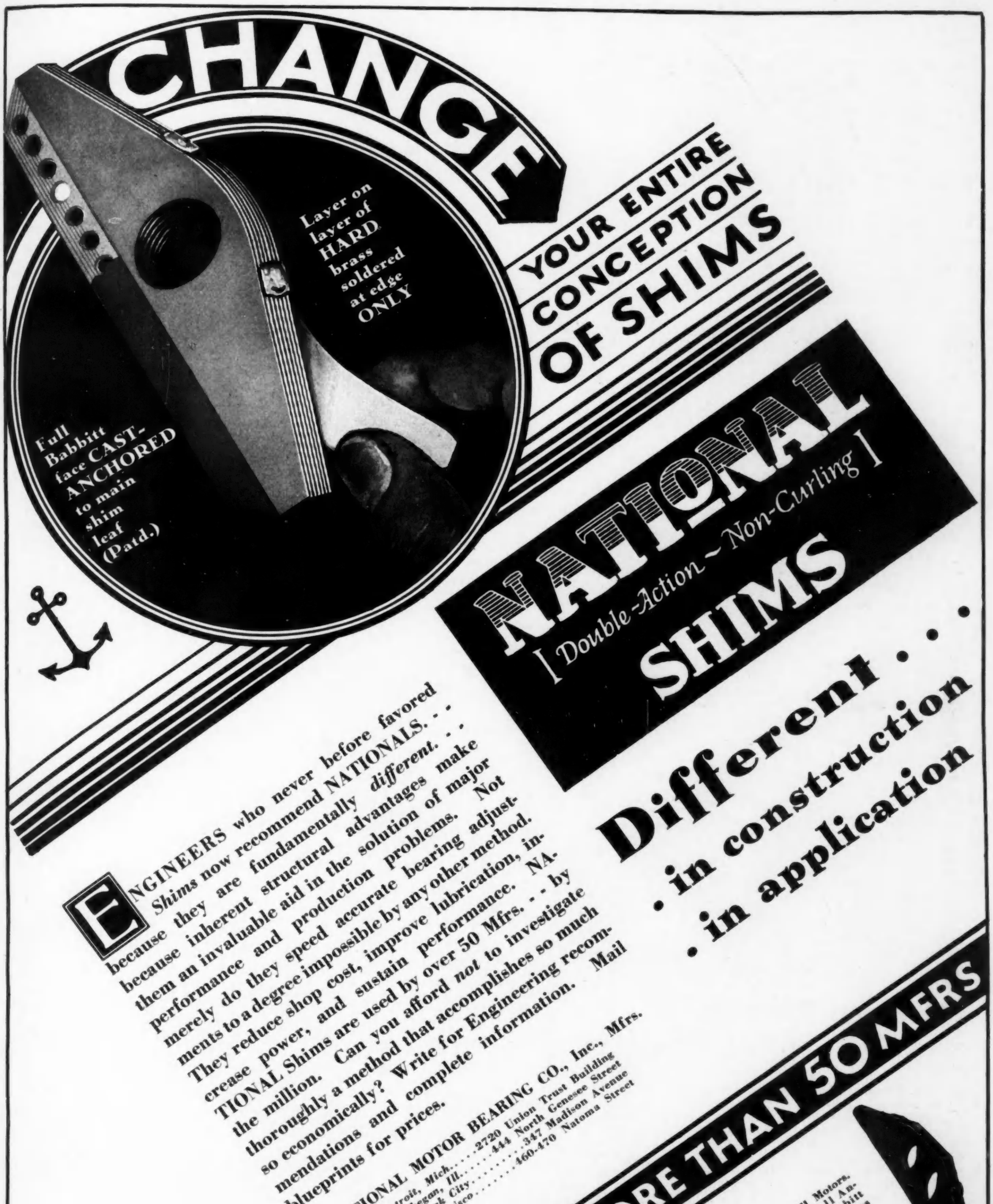
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Efficiency and reliability of airplane engines have improved with increased engine-speed and certain improvements in cylinder design. While reliability and sufficient performance are needed for the machine to be run at a profit, silent running is desirable for comfort, certainly in passenger traffic. Little progress, it is stated, has been made along this line, even in military circles.

There has been considerable improvement in detail in engine-driven fuel-pumps, which are an accepted accessory. Higher speed is obtained in new magnetos, and the weight has been reduced by the use of cobalt-chromium magnets. Spark-plug manufacturers have aided by providing better plugs.

Everyone is aware of the steady improvement in materials available for use in building engines and the amount of research that is being carried on in that field.

The paper was followed by extensive discussion by members of the Royal Aeronautical Society.

Les Roulements à Aiguilles et leurs Applications. By M. Pitner. Published in the *Journal de la Société des Ingénieurs de l'Automobile*, June, 1930, p. 1051. [E-1]

An unusual type of roller-bearing, graphically referred to as "needle bearings," is described in this article and the principles governing its operation are set forth. It was evolved several years ago in the search for a connecting-rod bearing that should be capable of carrying substantial loads, resistant to sudden shocks, light and unaffected by poor lubrication.

Needle bearings are stated to resemble roller-bearings but to be of relatively small diameter and great length. They are cageless and not guided, being held only in an axial direction. The basis of operation of needle bearings is said to be the capillary action of the lubricant, and this feature constitutes the distinction between them and roller-bearings. The assemblage of rollers or needles forms a bushing between the turning and the fixed parts, and turns only at a speed intermediate between the linear speeds of the outer and inner sleeves. The needles do not revolve about their own axes except in special cases.

The explanation given is that, in operation, a film of lubricant forms between the needles and their runway. Friction at this point tends to make the needles revolve. On the other hand, friction between the needles and the wedge-shaped mass of lubricant in the interstices between them tends to hold the needles stationary, and, the latter being the stronger force, the needles do not revolve.

A discussion is given of the favorable action of the needles under overloading and impacts, of design features needing consideration, and of their use in valve rocker-arms, crankshaft and camshaft bearings, water pumps and fans, clutches, transmissions and universal-joints.

Untersuchung über den Volumetrischen Wirkungsgrad an einem Zweizylinder-Zweitaktmotor mit Kurbelkammergemischpumpe. By F. Buchholz, L. Hoffmann and K. Joachimssohn. Published in *Automobiltechnische Zeitschrift*, July 31, 1930, p. 505. [E-1]

A series of tests was made to determine the efficiency of a two-cylinder two-stroke-cycle engine. The experimental procedure called for the measurement of engine torque, speed, fuel and air consumption, temperature of the outgoing cooling water, and exhaust-gas analyses. The results are plotted in curves.

Der Neue Hesselman-Motor. Published in *Automobiltechnische Zeitschrift*, July 31, p. 510, and Aug. 10, 1930, p. 535. [E-1]

In the new Hesselman heavy-oil engine the air is compressed and a rotating movement is set up in it. Toward the end of the compression stroke, small fuel-pumps, one for each cylinder, inject the fuel charge into the turbulent compressed air. The mixture is ignited by a spark. For partial load, the air supply is diminished. Gasoline and

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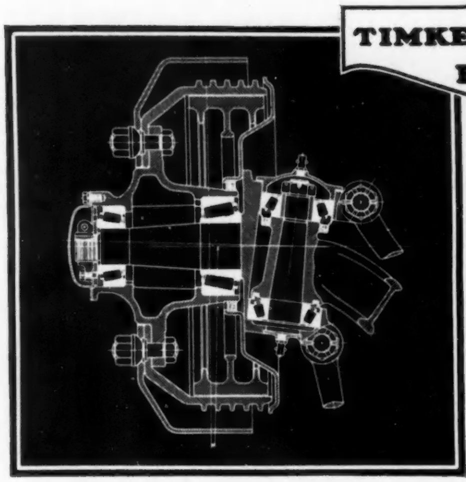

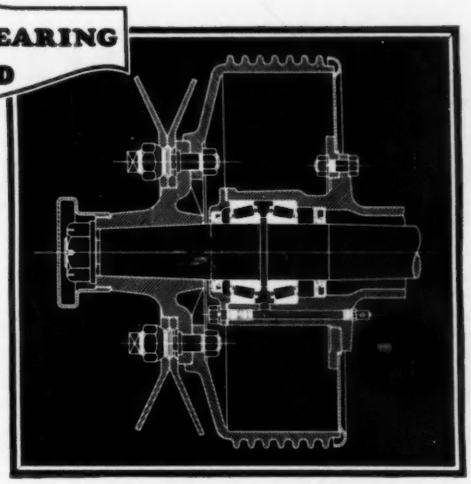

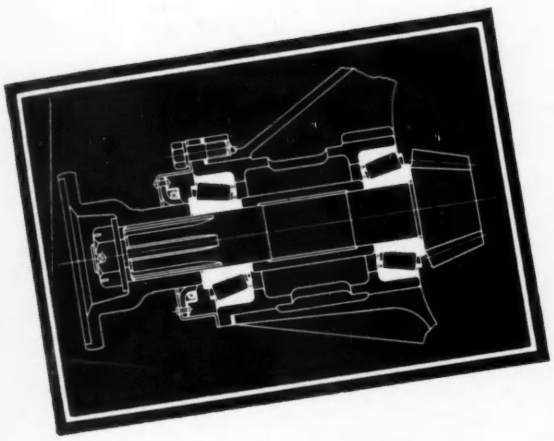

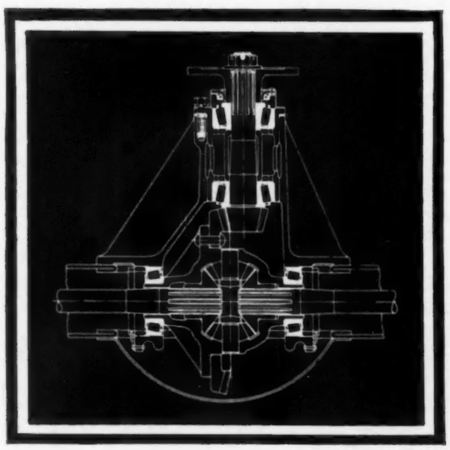

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an electric starter are used in the starting of the engine. The engine is described in detail, and results of tests made with it as a motor-truck powerplant are presented.

Fuel Distribution in an Automotive Engine. By L. C. Price. Bulletin No. 9, Engineering Experiment Station, University of Arkansas, Fayetteville, Ark., 1930; 34 pp. [E-1]

The results obtained in the experiments reported show that distribution changes with changes in speed and opening. The amount and direction of the changes depend upon the manifold and on the disturbances set up within the carbureter by the idling jet, the throttle disc, and the form of the carbureter air-passengers. The non-uniformity of the mixture in the carbureter throat may be compensated for in the manifold design so as to give perfect distribution at one condition of engine operation. The better the distribution, the more nearly do the maximum-power and maximum-economy mixtures for the engine as a whole approach each other.

HIGHWAYS

Philadelphia Traffic Survey, Report No. 5, West Philadelphia. Prepared under the direction of the Mitten Management, Inc., May, 1930, 36 pp. [F-1]

This report discusses the traffic characteristics of West Philadelphia. More than 30 plates and plans aid in grasping the situation without too much reading. An excellent system of main traffic arteries is recommended.

Other cities can benefit by a study of the proposed results, and the plans.

Report of the Committee of the American Engineering Council on Street Traffic Signs, Signals and Markings, 1929. Published by the American Engineering Council, City of Washington; 54 pp. [F-1]

After a careful survey of the best existing practice in the use of traffic signs, signals and markings in more than 100 cities, the committee has formulated some basic essential recommendations concerning the design, location and use of traffic signs as a means of increasing and facilitating traffic on city streets.

Ways and Means to Traffic Safety. Published by the National Conference on Street and Highway Safety, City of Washington, May, 1930. [F-1]

This bulletin is a summary of all recommendations of the National Conference on Street and Highway Safety. It recommends model State motor-vehicle laws and municipal ordinances, and standard traffic signs, signals and markings. Numerous recommendations are made for the education of highway users, and emphasis is put upon the imperative need for greater attention to proper maintenance of motor-vehicles by the individual owners.

Members of the Society who are interested in street and highway safety may be interested in the reports of the Committee on Protection of Railway Grade Crossings and Highway Intersections, the Committee on Measures for the Relief of Traffic Congestion and the Committee on Uniform Traffic Regulation.

Parts of the Uniform Vehicle Code, for example, Model Municipal Traffic Ordinance and Act IV—Uniform Act Regulating Traffic on Highways, both published in the City of Washington on June 28, 1930, may also be of interest.

MATERIAL

Specimens for Torsion Tests of Metals. By R. L. Templin and R. L. Moore. Paper presented at the 33rd Annual Meeting of the American Society for Testing Materials, Atlantic City, N. J., June 23 to 27, 1930. [G-1]

This paper describes tests made to determine the influence of form and size of specimen upon the results

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obtained in torsion tests. The merits of hollow cylindrical specimens, having different ratios of diameter to wall thickness and length to diameter, as well as those of solid sections, have been investigated.

The results indicate that, for determinations of shearing strength, the hollow specimen having a ratio of outside dimeter to wall thickness, D/t, of from 12 to 14:1 and a ratio of length of thin-walled section to diameter, L/D, of about 0.5:1 is satisfactory. Specimens having a D/t ratio of about 10:1 apparently are best suited for elastic-limit and yield-point determinations. Comparative results from hollow and solid specimens show little variation in values of the modulus of elasticity in shear. Some data are given pertaining to the influence of specimen proportions upon values of shearing yield-point obtained from autographic diagrams.

In conclusion, the authors express the opinion that the development of torsion testing offers a very profitable field for further study. A more extensive use of the test must be made before definite recommendations can be outlined.

Some Effects of Nickel Content in Austenitic Iron-Chromium-Nickel Alloys. By Norman B. Pilling. Paper presented at the 33rd Annual Meeting of the American Society for Testing Materials, Atlantic City, N. J., June 23 to 27, 1930. [G-1]

The chromium-nickel "stainless" alloys which are now drawing the attention of both the engineering world and the general public have certain undesirable properties that at times interfere with their fullest application. They include such qualities as excessive hardening on cold working, poor fabricability, loss of ductility both cold and at moderately high temperatures, loss of corrosion resistance, and weld decay.

The author points out that some of the austenitic chromium-nickel steels have the power of precipitating alpha iron under certain conditions of heat-treatment and strain, and the composition limits of this range have been approximately placed. Some of the detailed consequences of this instability have been traced, a point of special interest being that carbide precipitation is attended by more serious results when it is accompanied by the formation of a ferritic phase.

The completely stable type of alloy has at least two useful advantages:

(1) It assures a completely austenitic structure, which is essential in some electrical and high-temperature service.

(2) It has greater tolerance for higher carbon contents.

This latter property gives a desirable latitude in composition for those manifold applications in which appearance and fabricability are dominating considerations, rather than the ability to withstand the severest exactions of temperature and corrosion. It may best be achieved by a moderate increase in nickel content, the cost of which can largely be written off by the use of the less expensive grades of ferro-chromium. This is a possibility that should appeal equally to the steel maker and the user, and the economics involved deserve careful consideration.

The New Manganese-Alloy Steels. By E. E. Thum. Paper presented at the 33rd Annual Meeting of the American Society for Testing Materials, Atlantic City, N. J., June 23 to 27, 1930. [G-1]

Contrary to the report that the manganese addition should be held below 1 per cent so as to avoid brittleness in steel, the author declares that the alloy is very strong and tough if carbon is reduced proportionately as the manganese is increased. Well over 250,000 tons a year of such medium-manganese steels are now used in the United States, and this paper indicates the properties that

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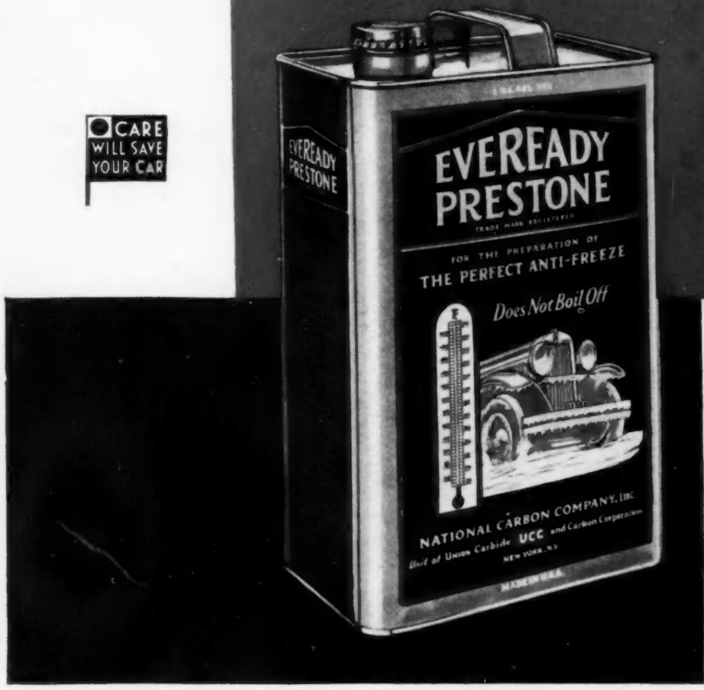
AN ANTI-FREEZE THAT IS FAVORABLE TO CONTROL OF MOTOR-TEMPERATURES . . .

EVEREADY PRESTONE



EVEREADY PRESTONE, by reason of its high volumetric heat, is unusually well-suited for use with modern motors, where its effect on automatic temperature-control is practically nil. Except in its capacity as an anti-freeze, Eveready Prestone is neutral . . . it will not boil off, overheat an engine, retard circulation at low temperatures, or damage any part of cooling-system. And it *will* give absolute protection against freezing during an entire winter.

Following intensive cooling-system research, both in the laboratory and in actual field-service, we have developed a New Eveready Prestone which has these outstanding points of interest:

1. It is green in color, to identify it.
2. There is less rust formed in the cooling-system, with the New Eveready Prestone, than with ordinary water—reducing the tendency of radiators to clog with rust. Furthermore, a solution clear to start with stays clear, with practically no rust in suspension.
3. Leakage is not a problem with the New Eveready Prestone. Any liquid can be lost from a system that is not leak-tight, and the industry has accepted the fact that cars should be properly serviced, according to manufacturers' instructions, in order to give the greatest satisfaction in the use of an anti-freeze.

We welcome the opportunity to co-operate in any tests you may wish to make of the New Eveready Prestone. Our facilities are available for this purpose.

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have been developed in the various uses. In the as-rolled and normalized condition they are used for steel rails, high-strength structural steel, ship plate and boiler plate, seamless steel tubing, and compressed-gas cylinders. In the heat-treated condition, medium-manganese steels, with or without another alloying element, find good use for such diversified parts as shock-resisting castings, high-test welding rods, carburized gears and machine parts, heat-treated forgings and press work, rifle barrels, leaf and helical springs, shear blades and non-deforming gages.

The Constitution of Steel and Cast Iron. By Frank T. Sisco. Published by the American Society for Steel Treating, Cleveland, Ohio; 332 pp. Price, $3. [G-1]

We have many conflicting views and opposing theories concerning the constitution of iron-carbon alloys with which this book is concerned. The author has presented the subject matter logically, beginning with concepts easy to understand and gradually taking up the more difficult theoretical considerations.

Subjects such as the constitution and structure of the alloys of iron and carbon, simple crystallization saturation, and equilibrium, crystal structure, amorphous solids and allotropy are discussed.

The way in which the author deals with iron-carbon alloys to which have been added one or more of the alloying metals—nickel, manganese, chromium, vanadium, tungsten, molybdenum and others—makes enjoyable reading.

It is evident that a great deal is known today concerning iron-carbon alloys, thanks to those scientists who have worked so untiringly with their transformation-point apparatus, their microscopes and X-rays.

The author has succeeded in his aim to help someone to a better understanding of the most fascinating and most important metallic materials known to man.

The Significance of Hardness Values for Some Copper-Zinc Alloys. By C. H. Davis and E. L. Munson. Paper presented at the 33rd Annual Meeting of the American Society for Testing Materials, Atlantic City, N. J., June 23 to 27, 1930. [G-1]

The effect of grain size on the hardness of both annealed and cold-worked alpha-phase copper-zinc alloys has been observed. The significance of variables that affect hardness values is shown by a series of curves.

Hardness values indicate:

(1) The grain size of any given annealed alloy

(2) The grain size of any given cold-worked metal if used in conjunction with the percentage of reduction

(3) The percentage of reduction of any given alloy when used with a grain size.

Hardness values for a given grain size change progressively from that of a pure copper to that of the alpha alloy of lowest copper content.

The hardness-value maximum near the center of the alpha range, which has been recorded by several investigators, is not observed, assert the authors, if any given grain size is taken as a basis for the hardness-chemical composition relationship. It is evident that this reported maximum is a function of the annealing temperature and the amount of previous cold-working.

A New High-Strength Aluminum Alloy (Hyblum). By Archibald Black. Published in *Airway Age*, June, 1930, p. 784. [G-1]

In recent years duralumin has won favor with aircraft designers. Now a new alloy, under the market name of Hyblum, has been invented. It weighs slightly less than duralumin and its cost is appreciably lower on account of the facility with which it can be rolled. Tests made upon

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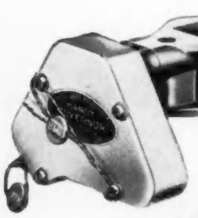

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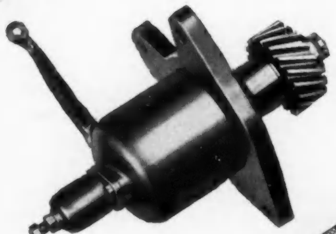

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Hyblum indicate, writes the author, that the material possesses qualities desirable in airplane construction. It has more ductility and resists corrosion from salt water better than the commercial grades of duralumin.

Flow Characteristics of Special Fe-Ni-Cr Alloys and Some Steels at Elevated Temperatures. By H. J. French, William Kahlbaum and A. A. Peterson. Published in the *Bureau of Standards Journal of Research*, July, 1930, p. 125. **[G-1]**

Conclusions reached from tests were that no marked changes were found in the hardness or impact resistance of these metals so long as no measurable deformation was produced in the prior flow tests. At temperatures at which strain hardening occurs, deformation in the flow tests produced a small increase in the hardness and a decrease in the impact resistance of the steel at atmospheric temperatures. Deformation in the flow tests at higher temperatures did not affect these properties at atmospheric temperatures.

Relationships between Rockwell and Brinell Numbers. By S. W. Petrenko. Published in the *Bureau of Standards Journal of Research*, July, 1930, vol. 5, No. 1, pp. 19 to 50. **[G-1]**

No discernable relationship was found between the tensile strengths of nonferrous metals and their indentation numbers.

Kritische Untersuchung des Schlag-Kerb-Faltversuchs nach Kr K 100. By Fritz Saeftel and Hans Rudolph. Published in *Automobiltechnische Zeitschrift*, July 20, 1930, p. 492. **[G-1]**

A critical examination is here made of the Fakra notched-bar impact-test Kr K 100, especially with regard to its suitability for determining the resistance to dynamic stress of bright drawn material. A series of tests was made, and is here described, in which several factors not specifically fixed by the conditions of the test as at present developed were varied.

The conclusion is drawn that the test, judged both by theory and the results of practical trial, is unsuitable for the purpose for which it was designed. In making the tests, the operator can alter a number of conditions having a profound effect on the results without violating the procedure laid down. Some of these factors are the diameter of the test piece, width of the notch and the instrument used in making it, and the position on the bar at which the impact occurs. The recommendation is made that the test procedure be revised so as to be more inclusive and detailed.

Laboratory Flexing Tests as an Aid in Investigating the Pneumatic-Tire Carcass. By H. A. Depew and H. C. Jones. Paper presented at the 33rd Annual Meeting of the American Society for Testing Materials, Atlantic City, N. J., June 23 to 27, 1930. **[G-1]**

In an investigation of laboratory methods that can be applied to the development of the pneumatic-tire carcass, it has been found that a pulley flexing-test using small belts gives information that should be applicable to high-pressure tires. A free-bend test gives additional information when very low air pressures are used, and a jerking test gives information regarding the quality of the cord.

Good insulation of the cords accentuates differences in ply separation, and therefore good insulation is the preferred condition when testing compounds for ply separation. This influence of belt construction on the flexing life of different compounds emphasizes the importance of studying tire construction in connection with the compounding of the pneumatic-tire carcass.

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Physical Characteristics of Parachute Cloth Under Varying Atmospheric Conditions. Air Corps Information Circular, vol. VII, no. 651. Published by the Chief of the Air Corps, City of Washington, 1930, 11 pp., illustrated. [G-1]

The conclusions drawn from the data provided from various tests are:

(1) With the moisture content constant, the following vary directly with temperature: porosity, Mullen strength, tensile strength and modulus of elasticity.

(2) With moisture content constant, the following vary inversely with temperature: elongation, regain and impact strength.

(3) With the temperature constant, the following vary directly with moisture content or relative humidity: elongation, regain, and, from all indications, the impact.

(4) With temperature constant, the following vary inversely with moisture content or relative humidity: porosity, tensile strength, Mullen strength and modulus of elasticity.

(5) With the relative humidity constant, the following vary directly with absolute moisture content and temperature: elongation and regain.

(6) With the relative humidity constant, the following vary inversely with the absolute moisture and temperature: porosity, tensile strength, Mullen strength and the modulus of elasticity.

(7) For any atmospheric condition, the tensile strength the Mullen strength, the porosity and the modulus of elasticity vary directly with each other and inversely with the moisture content.

(8) For any atmospheric condition, the elongation, the regain, and, in all probability, the impact strength, vary directly with each other and directly with the moisture content.

Evaluation of Lubricating Oils by the Work-Factor Method. By J. G. O'Neill and F. M. McGeary. Published in *National Petroleum News*, June 11, 1930, p 63. [G-1]

The data obtained from the tests reported show that the results are reproducible on the type of machine used; also that the machine discriminates between poor and good lubricating oils. Conclusions drawn are that the regularly used standard specification tests are of little value in showing the quality of lubricating oil.

In the past, when dealing with the value of a lubricating oil, much emphasis has been placed upon consumption and little upon the unnecessary wear of parts and the consequent cost of repairs.

The most useful purpose of the work-factor method of test is to create an incentive to lubricating-oil producers to produce oils of higher quality than will just get by the minimum accepted requirements. Their higher cost would be offset by a general lowering of repair costs.

Relative Resistance of Lubricating Oils to Decomposition in Use. By E. R. Lederer and E. W. Zublin. Published in *National Petroleum News*, August 13, 1930, p. 63. [G-1]

In reviewing the life test for lubricating oil by the Navy Engineering Station, the results of which appear in the preceding paper, the authors of the present paper feel that the drawbacks of the work-factor method lie in the fact that a number of values are used. Such specifications, they feel, are subject to criticism.

The tests should be made for a longer period and with several types of engine at different temperatures, because it is known that the increase in viscosity of naphthenic and paraffinic oils over a 100-hr. period is considerably larger for naphthenic than for paraffinic oils. Also, the tests should be made on actual performance, because laboratory tests are subject to criticism.

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Detonation and Lubricating Oil. By R. O. King and H. Moss. Published in *Engineering*, July 11, 1930, p. 31. [G-1]

Experiments were conducted upon a Ricardo E-35 variable-compression engine at the relatively low engine-speed of 900 r.p.m. because at this speed the H.U.C.R. (highest useful compression ratio) for gasoline A is low and a large addition of benzol or metallic dope can be used without increasing the H.U.C.R. to such a high value that its accurate determination is difficult. This engine was used because of its low rate of oil consumption. Its standard valve-timing is arranged for the best possible volumetric efficiency at 1500 r.p.m.

Reviewing the results of nickel carbonyl, lead tetraethyl and benzol with various lubricating oils, in all cases the effect of the oils reached a maximum as their proportion in the fuel oil was increased. The effect of castor oil on the iron dope was similar to that of the rape oils, but when using nickel dope it was similar to that of olein and oleic acid. The oleic acid was less effective in destroying the beneficial effect of the lead dope at high than at low induction-temperatures. The opposite effect was observed when oil was used in gasoline containing iron carbonyl.

When fuels of dissimilar composition are matched with respect to detonation, the results obtained vary with the conditions of engine lubrication. This is because the rate at which the oil passes into the combustion space depends on the continually changing mechanical condition of the piston, piston-rings and cylinder bore.

In the various methods of temperatre control, the resulting differences are greatest when fuels containing benzol are matched against others containing a metallic dope.

The economic advantage of fuels given a high antiknock value by benzol or ethyl fluid used at normal induction-temperatures is lessened when they are used in supercharged engines.

The article is continued in the July 25 issue of *Engineering*.

The Valuation of Motor Fuel and Lubricants. By Harold Moore. Published in *The Journal of the Institute of Transport*, June, 1930, p. 380. [G-1]

Crude petroleum is a very complex mixture containing innumerable different chemical substances that vary greatly in boiling-point. In practice, distillation has been found to be the most satisfactory and economical of the many ways employed to split up the crude oil.

Specific gravity is not regarded as a measure of volatility, but taken in conjunction with distillation it is used as a rough check on aromatics. The heavier-gravity product gives greater motor-car mileage per gallon.

Petroleum value can be determined by a few simple tests, but there is no simple valuation of lubricants.

Motor Performance as Determined by Fuel Volatility. By George Granger Brown. Paper presented at the 33rd Annual Meeting of the American Society for Testing Materials, Atlantic City, June 23 to 27, 1930. [G-1]

The ease with which an internal-combustion engine will start, the time required to warm it up, and the character of its general performance are almost wholly dependent upon the volatility of the fuel as indicated by the A.S.T.M. distilation curve. The 10-per cent point, states the author, is related to the lowest engine temperature at which satisfactory starting can be obtained and the lowest mixture temperature at which the car can be operated. The 35-per cent point is related to the lowest mixture temperature at which satisfactory performance can be obtained during the warming-up period and therefore determines the length of time necessary to warm up the engine.

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The 65-per cent point is related to the lowest mixture temperature at which perfect performance can be obtained.

For these reasons the 10, 35 and 65-per cent points should be low to assure satisfactory starting, warming up and general performance. The 90-per cent point, however, should not be so low as to indicate a dry mixture, for this means loss in power or acceleration with many modern cars equipped with heated manifolds and accelerating devices. The vapor pressure of the fuel or the 10-per cent point should not be so low as to indicate trouble from vapor lock.

The relations presented in this paper make it possible to determine the volatility characteristics of a fuel for any desired engine performance.

Ghost of Sulphur in Gasoline Costs Americans 50 Millions a Year. By Gustav Egloff, C. D. Lowry and Paul Truesdell. Published in *National Petroleum News,* June 11, 1930, p. 41. [G-1]

The gasoline authorities of the various countries differ as to the amount of sulphur permissible in motor fuel. As far as general use is concerned, there is very little restriction, but most countries have rigid limits with regard to the quantity of sulphur in aviation fuels. The limits range from 0.10 per cent in the United States and Spain to no sulphur at all in Czechoslovakia.

The United States is the only country in which corrosion is attributed to sulphur in gasoline. Motor fuels such as those used in England and Germany have a comparatively low sulphur-content. In those countries 0.2 per cent is customary, but in practical use a much lower sulphur content is found.

The question is debatable and is in need of handling. This article is the first in a series of three.

Oils, Tractor Fuels, Gasoline and Kerosene. Bulletin No. 27, Office of State Food Commissioner and Chemist, Bismarck, N. D., April, 1930. [G-3]

This is a technical report by the inspectors of kerosene and fuel oils in the State of North Dakota, giving the State specifications for gasoline and kerosene; complete data on laboratory test results of all the different fuels and how the samples met the State specifications; and the total gallonage of gasoline and kerosene received by each town and by each company operating in North Dakota during 1929. The first three pages of the Bulletin list the many motor-vehicle and tractor lubricating oils according to S.A.E. Viscosity Numbers.

La "Politique" Française du Pétrole. By A. Grebel. Published in *Le Génie Civil,* Aug. 2, p. 105; Aug. 9, p. 130; and Aug. 16, 1930, p. 154. [G-5]

Where and how shall France obtain her petroleum supply? How can the correct answer to this question be extracted from the confusion of political issues and prejudices, personal opinions, and technical and pseudo-technical discussions which surround it? Focusing upon the problem his 30 years of observation, the author reviews the history of petroleum, its sources of supply, its production, export, import, consumption, and the amount of capital and type of commercial organization involved in its exploitation; looks abroad to see the political and commercial measures taken by other countries to ensure their own supply, and reviews the attempts of France to achieve that end, notably her efforts to secure petroleum concessions, her participation in the San Remo pact, and the legislation of March 16 and 30, 1928, and its administration.

Mr. Grebel's advice is not to discourage the activities of foreign entrepreneurs in France; but to admit them and play them one against the other; in other words, to divide among different countries and controlling financial groups the responsibility of securing an adequate liquid-fuel supply. In the second place, France should lose no time in obtaining

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concessions in foreign fields not already occupied and where French interests should predominate. The encouragement of native refineries and means of transportation should be seriously considered. Finally, the possibility of developing substitute fuels should not be wholly lost sight of, although such fuels are for the most part too costly for use in normal times.

MISCELLANEOUS

A New Consistometer and Its Application to Greases and Oils at Low Temperatures. By Ronald Bulkley and F. G. Bitner. Published in the *Bureau of Standards Journal of Research*, July, 1930, p. 83. **[H-1]**

The authors of this report came to the conclusions that the consistometer described is fast in operation and makes possible the taking of any number of flow-pressure graphs at the same or different oil or grease temperatures without refilling or removing from the bath. It is suitable for materials that change in consistency with time or with mechanical working. It possesses the unusual advantage that it can be used to measure either the unworked or the worked consistency of plastic materials of any temperature. These are the properties generally recognized as most useful in characterizing such materials.

Certain oils at low temperatures show the property of thixotropy and require a standardized period of cooling to assume a reproducible consistency.

Ingenious Mechanisms—For Designers and Inventors. Edited by Franklin D. Jones. First edition, published by The Industrial Press, New York City, 1930; 536 pp. Price, $5. **[H-1]**

This book replaces Mechanisms and Mechanical Movements, published in 1918, of which the editors retain the best material in the present volume. This material, with the addition of the new, makes the treatise of great value to the designer and draftsman.

The present 536-page volume contains illustrations and descriptions of a large variety of standard and special mechanisms that have stood the test of practice. The important elements or units in automatic-machine design are made very clear.

In addition to a very thorough index, the mechanisms described are grouped into chapters according to general type to facilitate finding the class of mechanical movement desired.

This compilation of selected material by experienced designers deserves the attention of all men in this field.

Weld Design and Production. By Robert E. Kinkead. Published by the Ronald Press Co., New York City; 108 pp. Price, $4. **[H-5]**

This volume constitutes a reliable source of information concerning design, production, service and cost of welds. It also deals to some extent with welding conditions, procedure control and the effect of physical conditions on weld behavior.

Welding Jigs and Fixtures. By J. H. Hardecker. Published in *Aviation*, July 5, 1930, p. 4. **[H-5]**

Welding jigs speed up the actual operation of welding and facilitate the cutting of component tubes to exact length in quantity, thereby leading to interchangeability of fabricated units. Another advantage is the accuracy of alignment obtainable, which is very essential in airplane construction and the control of shrinkage and warpage.

Results of the study upon current practices of representative factories show, according to the author, that the simplest welding jig which will answer the purpose is the best.

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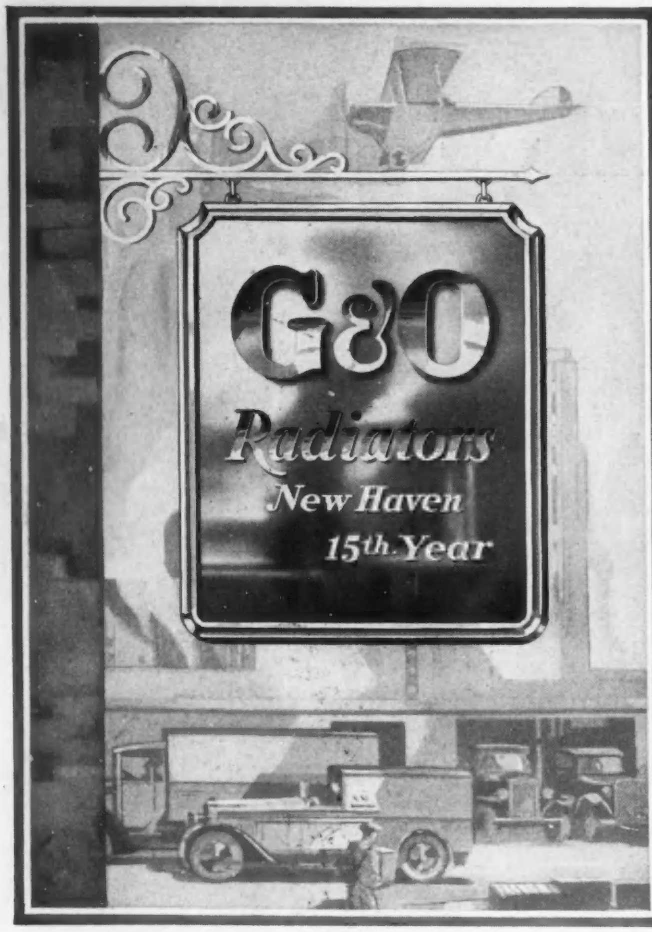

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Good welding-jig design is a combination of technique, good judgment and common sense. To some extent it is dependent upon experience, and to a far greater extent upon the ability to profit by one's own mistakes.

L'Industrie Automobile Allemande. By G. Lienhard. Published in the *Journal de la Société des Ingénieurs de l'Automobile*, June, 1930, p. 1042. **[H-5]**

The French automotive industry should join with that of Germany, asserts Herr Lienhard. Its contribution should be capital, which it has in abundance, and engineering brains; Germany's should be the disciplined industry that is one of its ingrained characteristics. France should not neglect the German automotive market; while its possibilities at present are meagre, the future potentialities are great. The community of interest thus formed would represent a group of 1,000,000 inhabitants, which, if not as large as the American automotive public, would be sufficiently large to be commercially attractive.

This is the advice given by the author at the conclusion of his analysis of the German automotive industry and the lessons to be learned from it by France. Throughout all the vicissitudes experienced by the German automotive industry during the last decade, one dire shortcoming that has proved its undoing, he writes, is the inability correctly to perceive the modern trends and adapt its manufacturing methods and designs to postwar conditions.

Reasons advanced for the lack of automobile usage in Germany are that the people as a whole are poor, the middle class, the fecund field of quantity demand, having almost disappeared; dealer organization has not been properly and profitably built up; the highway system is undeveloped while railroads are highly organized and efficiently run; country riding is unenjoyable because of lack of scenic attractions; urban automobilism is hampered by cumbersome traffic regulations and the prohibition of garages within city limits; and, finally, the formalities of obtaining car and driver licenses are unduly burdensome.

Lessons that France should learn from Germany are that taxation according to piston displacement should be systematically combatted; standardization should be further developed and research should be energetically prosecuted, with the aim, not necessarily of producing a cheaper product, but a better product at prevailing prices.

MOTORCOACH

The Motorcoach Engine, Yesterday, Today, Tomorrow. By Carl Abell. Published in *Railway Age*, Section Two, Aug. 23, 1930, p. 394. **[J-3]**

The last eight years have seen remarkable changes in engine design to produce increased power and endless improvements in equipment. Eight years ago a standard motorcoach, seating 22 passengers, weighed about 8000 lb.; today's type weighs from 12,000 to 15,000 lb. and is much longer and wider.

The most noticeable factor in today's motorcoach engine is the increase in power provided by a jump from four to six cylinders of about the same bore and stroke, then gradual improvements and refinements involving changes in dimensions.

Today's motorcoach is twice as heavy as that of eight years ago, and today's mile is run at a much faster pace.

Other changes noted by the author are: improved cooling systems, aluminum-alloy pistons, development in the balancing of moving parts, elimination of destructive forces in the engine, and better bearings and crankshafts.

Mr. Abell is of the opinion that the motorcoach has reached the zenith of demand for power and that the improvements look toward fuel, its distribution to the cylinders, cold carburetion and increased displacement.